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EDITORIAL.

ITEMS AND NOVELTIES.

An Improved Testing Machine, *Manufactured at the Philadelphia Scale Works.*—The frontispiece of our Journal for May is a photo-plate, by Rehn & Dickes, of one of Riehle Brothers Improved Testing Machines of 40,000 pounds capacity. The frame is of seasoned oak timber, stands nine feet high, and the whole apparatus weighs about 2000 pounds. It consists of a compound parallel beam, grips for holding the test pieces, and a hydraulic jack and pump.

The beam is suspended by the upper clevis and the jack is secured to the frame below, and the proper tools and piece for testing are placed between the beam and jack, connected to the former with the lower clevis, and to the latter by a yoke.

Now the strain is applied by the jack and pump, and the weighing beam kept in equipose by the weights and weighing apparatus, and by that means actually weighs upon the beam the strain that the test piece is being subjected to. The treadle that is below the frame is for the purpose of raising the jack after it has been forced down in applying the strain.

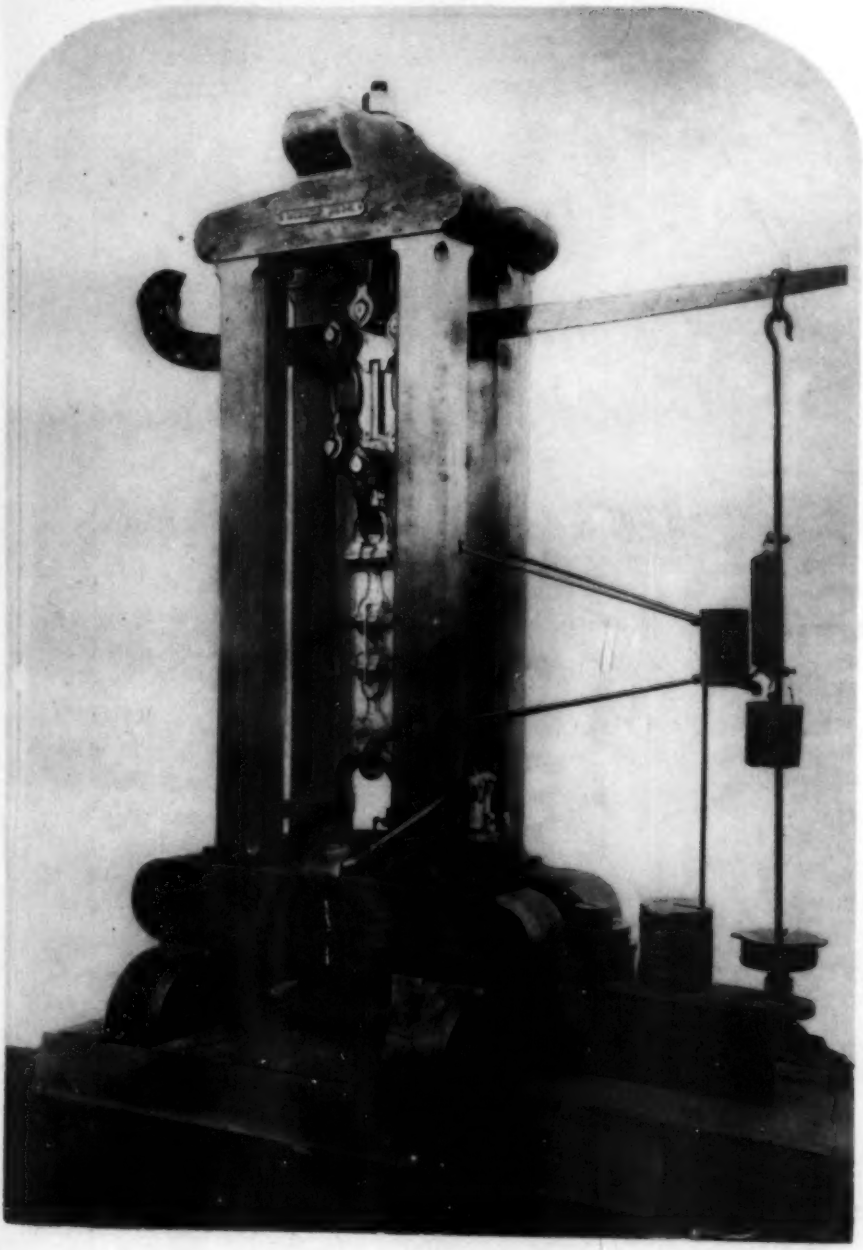
In order to weigh the strain with great accuracy, a self-acting weighing apparatus is attached, consisting of two reservoirs, one containing small shot and secured to the frame of the machine; the other one empty, and suspended to a spring dial, which is fastened to the

weight rod. On this rod is a finger point which, as soon as the beam is out of equipose and raises, lifts a trap, and lets flow a sufficient quantity of shot from the reservoir that is fastened to the frame of the machine to restore the equilibrium of the beam, which, when done, the flow of shot ceases. The amount of weights on weight dish, together with the weight of shot registered on spring dial, will indicate the amount of strain the test piece stood or at which it broke, as the case may be. By the use of this style of beam and jack with proper levers, machines can be made for applying all kinds of strains to all kinds of material, in any form, such as iron or stone columns, girders, bridge bolts, wire and hemp rope, chain, boiler plate, &c., &c., including the torsional strain. On this machine have been made some interesting tests for the Baldwin Locomotive Works; also for boiler plate manufacturers. This machine has been in use for several years, and after being subjected to the severest use, and frequent comparison with what is known as the "Government machine," has given great satisfaction. It is claimed that this machine can be made at less cost than any other of the same capacity, and for simplicity of construction and great strength, it appears to possess decided advantages.

Dank's Rotary Puddling Furnace.—The accompanying plate represents a perspectlve view of the machine puddler, which has recently attracted so much attention from the iron workers of this country and of England.

The immense advantages which would result from the construction of a machine by which the tedious manual operation of the ordinary puddling process might be performed mechanically, and with greater rapidity, certainty and regularity in quality of the product, have long been perceived by iron masters, and several attempts to solve the desirable problem have from time to time appeared; but not until the presentation, by Mr. Danks of his invention and the announcement of its performance, has this great desideratum approached a practical realization.

Upon the presentation of its claims before the British "Iron and Steel Institute," towards the close of the last year, this Association, with a promptness which affords the best evidence of the intelligence of its members, appointed a committee to visit America, in order to personally inspect and to report upon the operation of the machine puddler. The labors of this committee are now finished, and its report has just been published. This report is a practical acknowledgment of the successful solution of the problem of machine puddling, and a



IMPROVED TESTING MACHINE, Manufactured at the Philadelphia Scale Works.

confirmation in every essential feature of the inventor's statements; and as such must be hailed with gratification as an assurance that another important step in advance has been made in the chief of the metallurgic arts. As a practical result, highly satisfactory doubtless to the inventor, we learn that an agreement has been entered into by Mr. Danks and a combination of English iron manufacturers of various districts, whereby the latter undertake to have 200 furnaces, on his plan, erected within six months, and, as a consideration, they agree to pay him at that time £50,000.

The following is a general description of the furnace and accessories condensed from the report above referred to:

"Dank's rotary puddling furnace consists of a horizontal revolving chamber, which chamber intersects the fire-grate and an elbow flue leading to the uptake of the chimney. The shape of this chamber, when fettled, partakes of an ellipse. The two ends are brought in by means of two cast iron rings forming a portion of the outer framework or structure. This structure rests by its periphery on four cast iron friction wheels, fixed in framings, and it revolves between the fixed grate or fire-place and the elbow-joint above referred to. The furnace is driven by a pair of vertical reversible trunk engines, the spur wheel on the crank shaft being geared direct into a toothed wheel forming the periphery of the rotary furnace. The rotary portion referred to is formed of several cast iron segments, which are held together by means of two cast iron rings before named, one at each end slipping over the ends of the said castings. The inner shape of the castings which form the chamber is a series of dovetails running longitudinally, which are for the purpose of mechanicaliy holding in the fix or fettling.

"The fire-grate is similar in construction to that of an ordinary furnace, the bridge being built in the end of the grate. It is provided with a pair of folding doors, which, when closed and dabbed with clay, form a closed chamber. Air is provided by means of a fan, or blower —a portion is taken horizontally above the fuel, but the bulk is driven in underneath the bars.

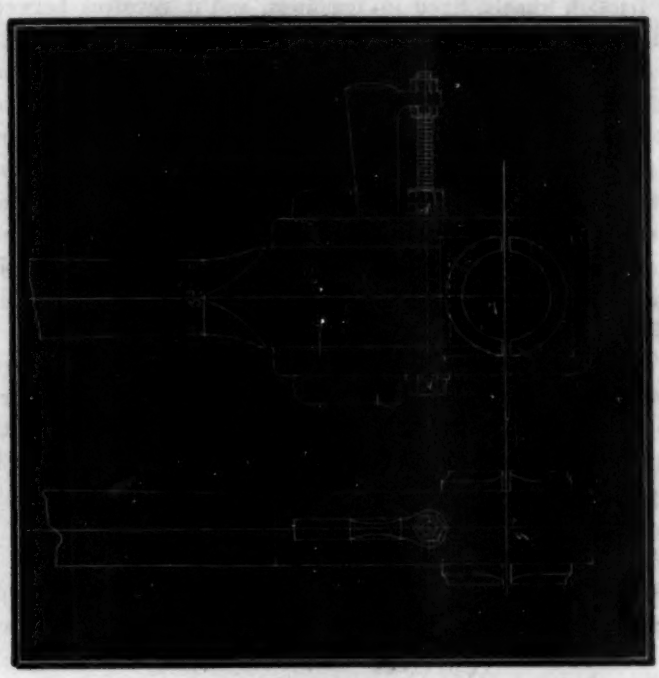
"The elbow joint, above referred to, forms the flue end of the whole apparatus, and it makes a short turn at right angles leading to the uptake of the chimney. The object of having this elbow connection is to allow of its being readily removed, in order to get at the interior of the revolving chamber. The piece, or connection, is suspended to a way above by means of a chain attached to a pinion,

which pinion runs into a rack above. A pulley and chain are fixed on the same axis as the pinion, and, by means of these, the apparatus is removed and replaced at will.

"The two rings, forming the ends of the fire-bridge and elbow joint, are provided with water pipes cast in them, by which means they are kept cool."

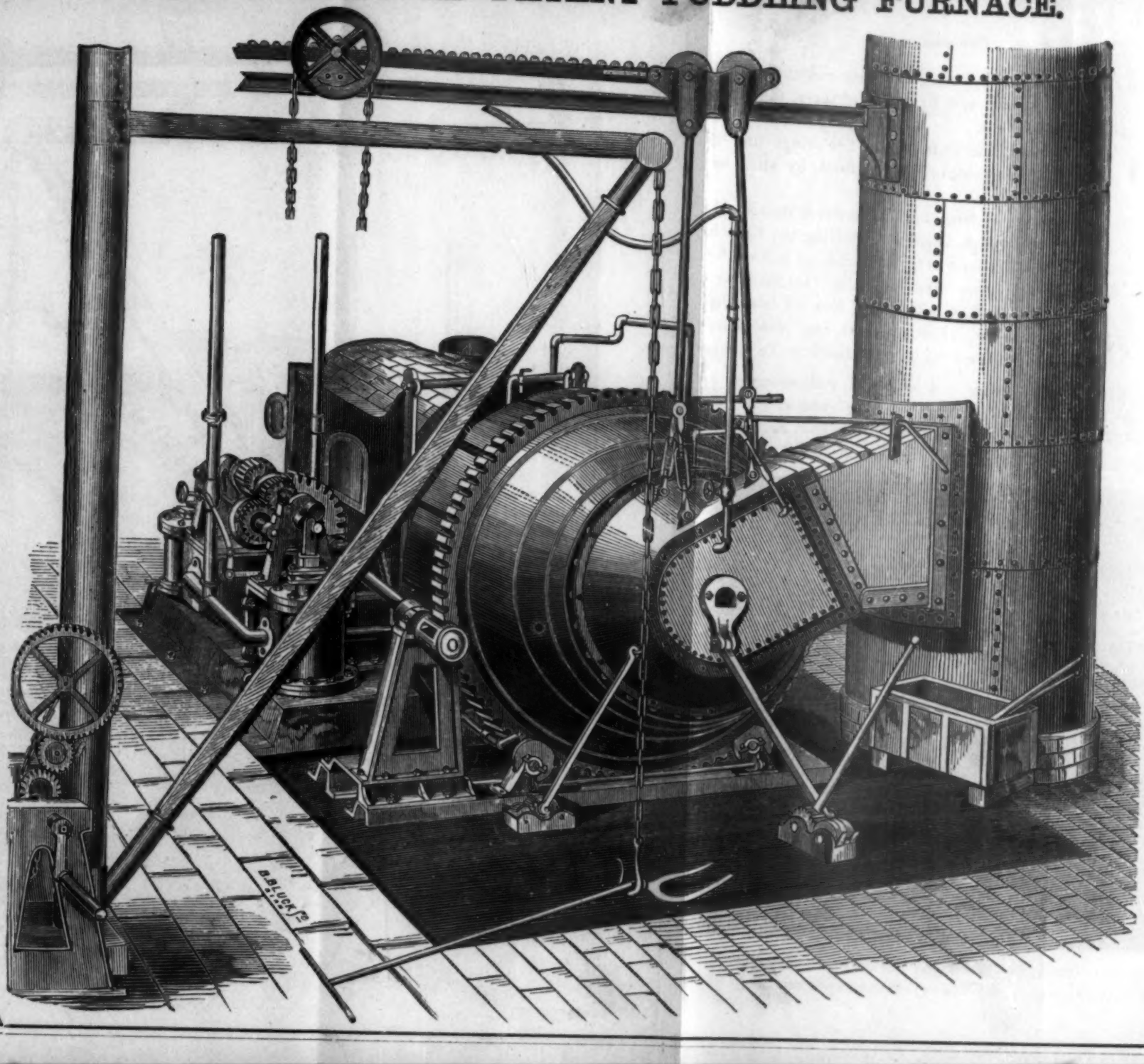
The tools for charging and removing the product consist: First, of a charging pan of scoop shape, capable of holding the full charge of pig together with the squeezer slag. Second, of a fork for removing the charge, which is operated, as is also the charging pan, with the aid of a crane. Third, of a receiving fork for receiving the ball and conveying to squeezer. The squeezer has been somewhat modified to work the heavy masses of iron produced in the furnace.

A New Stub-End.—Below is a sketch of stub designed by the writer for the crank-pin end of the connecting rods of four vertical engines of 400 horse-power, now building at the Port Richmond Iron Works, of this city, for a rolling mill at Scranton, Pa. Their shafts



are to attach directly to the trains of rolls, and consequently a high speed is required, or seventy-five revolutions per minute.

DANKS' IMPROVED PATENT PUDDLING FURNACE.



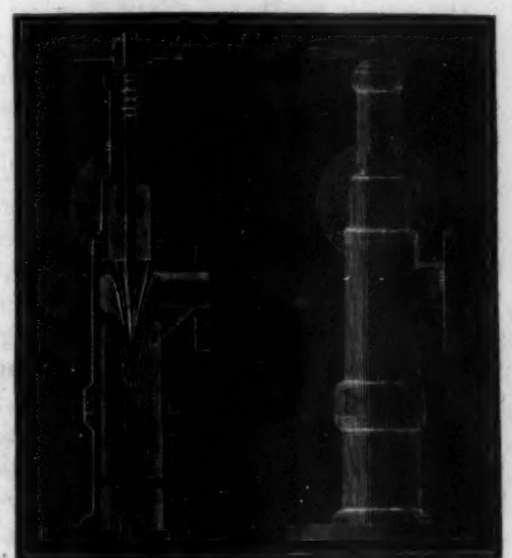
The connecting rods are heavy, having necks of 5¾″ diam., and boxes to suit a pin of 7″ diam. by 9″ length, and the blow resulting from the change of motions strongly tends to make the strap gape on alternate sides.

To counteract this the bolt A is passed through very near the end of stub, the strap having oblong holes to allow for draft.

To hold the key in adjustment, and from flying out, a continuation of the same bolt, but of reduced diameter, passes through the lug B, of key, which it holds by nuts on each side. The rest of the parts are made in the usual way, except the stub, which is somewhat longer than ordinary.

Whilst no novel parts are introduced, the combination of old features is believed to be new, and the removal of the holding screw from its customary place on the gib head avoids the difficulties of making and keeping straight those of large size, and for the same amount of draft the key can be shorter, as the height of the nuts on bolt is less than that of gib head. W. J.

Bourne's Feed-Water Heater.—"This feed-water heater embodies a new principle in mechanics, namely, that of forcing water by a pump through a small orifice at such a velocity that its energy enables it to enter the boiler.



"But the naked jet being passed through the waste steam from the engine condenses part of this steam, and is thereby itself heated to (200°) nearly the boiling point.

"The figures give an elevation and section of the instrument for effecting this object.

"The water is conducted from the feed-pump through the highest pipe, and the waste steam from the engine through the second highest, while the lowest opening is an

escape-orifice for superfluous water. The instrument in its configuration resembles a Giffard's injector. But the water enters at the point where the steam enters in that instrument, and the steam enters where the water enters; so that this instrument is the converse of the injector." J. H. C.

The American Steamship Company.—From the report presented at the first annual meeting of the stockholders of the company, held at the rooms of the Board of Trade, Philadelphia, it appears that a contract has been entered into with the Messrs. Cramp, Philadelphia, for the construction of four first-class iron propellers, all to be alike in model and machinery, and the material to be used in their construction to be, as far as practicable, of American manufacture.

Each vessel is to be of 3,016 tons (old measurement), 355 feet in length, 43 feet beam, and furnished with compound, vertical, direct-acting, surface-condensing, propelling engines. They are to be arranged to carry 76 first-class and 854 steerage passengers, and the total cost of the four is to be $2,080,000. It is expected the first of these vessels will be launched in June next, and the last in January, 1873.

The Detroit River Tunnel.—The following account of the present condition of this work has been made public:

The shaft on the Detroit side of the river was commenced early in December, 1871, and finished in January, 1872, when bed-rock was reached at the depth of 108 feet below surface of river. The whole depth of masonry is 114 feet. The lower twenty-five feet of this has a diameter of nine feet, with 12-inch walls. The drainage tunnel or drift starts from the lower portion of shaft, 8 feet above the rock. The drainage drift has been excavated under the river to a point 130 feet from the shaft, a daily average of over five feet. The ground through which it passes is a very hard clay, which must be dug up with picks. A layer of large boulders was met with in this stratum, some of which had to be removed by blasting, rendering the progress of the work slow. Should this layer fortunately dip beneath the level of the drift, the progress of the work would be at once doubled.

The hardness of the clay affords ample security for the work, portions of this drift having stood for a week without support, and without exhibiting any signs of sinking.

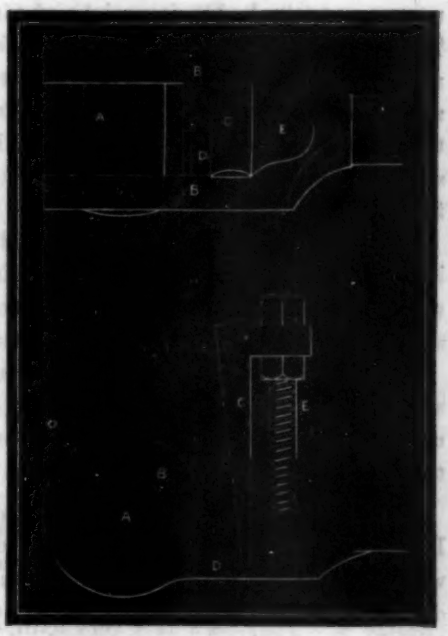
The lining, which is generally built within a day or two after excavation, is an 8-inch circle of the hardest bricks, previously tested, and laid in hydraulic cement.

Within a few days work will be commenced on the shaft Windsor, and as soon as it is sunk the drainage tunnel will be excavated from it to meet that now being worked from this side of the river.

From what was learned of the nature of the ground in sinking the shaft, it is anticipated that the main tunnels will be surrounded on all sides with good solid blue clay.

The progress of the work has thus far been very satisfactory, and there is every reason to believe that it will rapidly be brought to a successful termination.

A Joint.—A simple and neat adjustable joint is made by adapting a bearing block D to the outside of the eye-end through which the pin A goes, and which is made truly cylindric and concentric with the pin for that purpose.



The block is adjusted by the key C, which is forced and secured by the bolt and jam nuts E. The pin A is fastened to the fork B by a cross pin or other known means. The blocks D may be made by forming four together in one pattern, boring them out while thus united and facing sides in the lathe, then cutting them apart and fitting each to its place.

J. H. C.

A Permanganate Battery.—Mr. J. H. Koosen has experimented upon the substitution of permanganate of potassa for the nitric acid of the Grove Platinum Battery, and asserts that the electromotive force of this combination is greater than that of the Grove.

The following combination—platinum in a solution of permanganate with $\frac{1}{10}$ of sulphuric acid added, and amalgamated zinc in diluted sulphuric acid—gave the electromotive force as the average of more than one hundred measurements, to be between 1·9 and 2·2 (Daniel, 1.)

Preparation of Artificial Alizarin.—The important discovery by Graebe and Liebermann, namely, the artificial production of alizarin, the coloring principle of the madder, has as yet borne no decided practical fruits, from the laborious and costly nature of the operations involved. That it is not altogether overlooked by those engaged in the manufacture and use of dye stuffs will appear from the fact that quite recently two processes for the manufacture of alizarin have been patented abroad. That of Messrs. Bronner and Grutzkow, of Frankfort, consists in obtaining anthracene by the distillation of asphaltum with superheated steam. This is converted into anthrachinone by treatment with double its weight of nitric acid (sp. gr. 1·3 to 1·5). This is dissolved in warm sulphuric acid, and nitrate of protoxide of mercury is added. This compound is treated with an alkali, and the resulting solution is precipitated with an acid. The product thus obtained contains variable quantities of alizarin and purpurin. Redissolving in alkali and reprecipitation with acid is resorted to for purification.

Dale and Schorlemmer proceed as follows: One part of anthracene is boiled with four to ten parts of sulphuric acid, diluted with water, neutralized with a carbonate (of baryta or soda, &c.), and the resulting sulphates removed by filtration or crystallization.

The liquid is then digested with a caustic alkali, to which has been added a quantity of nitrate or chlorate of potash, and this continued until a blue-violet color is no longer produced. From this product the alizarin is obtained by precipitation with an acid.

Fluorescence.—At a recent meeting of the American Institute, Professor Morton read a paper on "Fluorescence," or that action by which rays of the higher purple, or even invisible light, such as produce most strongly photographic action, excite in certain bodies lower rates of vibration, resulting in the emission of light, generally of a red, green, or clear blue color. This paper was illustrated by a number of striking experiments. Thus, a flask of solution of chlorophyl (a green coloring matter obtained from leaves), which is of an olive-green color, being held in a beam of blue light proceeding from a "vertical lantern," appeared to be full of a blood-red liquid. Various solutions, colorless in ordinary light, were then shown to exhibit the brightest hues when illuminated by the violet rays of the lantern, or those obtained from the electrical discharge of the Professor's large coil in rarified gases. The speaker then announced that in the course of the examination which he had been making of such substances, he

had encountered one which he believed to be as yet unknown, and which possessed the property of developing light by fluorescence in a pre-eminent degree. This body was obtained from petroleum, and he would propose to take for it the name "Viridine." The word viridine had been already applied as a synonym for chlorophyl, but was now practically obsolete, and too appropriate to the present substance to be thrown away. The material from which this new body was extracted was given to the speaker by Prof. Horsford, of Cambridge, Mass., and by him in turn received from Dr. H. C. Tweddle, of Pittsburg, Penn. A large drawing of a flower, with leaves painted seemingly in light umber tints, was then shown and illuminated by electric discharges, when it appeared of the most vivid green. The peculiar fluorescent spectrum of this body, and its relations to the spectra of other substances was explained, and many other illustrations were exhibited.

Lithofracteur.—From Mr. Abel's recent analyses of this explosive, which, from the prominence given to it during the recent war, bids fair to play an important part in warfare as well as in the arts of peace, its composition is given as follows:

Nitro-glycerin,	42 parts.
Nitrate of soda,	25 "
Sulphur,	4 "
Sand, siliceous earth, saw-dust and coarsely-powdered coal,	29 "
	100 "

From the recorded statements concerning its properties, it appears that it may be cast into a fierce flame without explosion. It may be subjected to heavy blows with the same result; but when fired by a detonating fuse it explodes with inconceivable violence. A recent practical illustration of its efficiency was given a few weeks ago in the removal, with three charges of this material, of a wreck in an English river, which seriously impeded navigation. The first charge of fifty pounds, placed in the after hatch, sufficed to remove the whole of the after part of the sunken vessel; the result being the projection of a huge mass of water, sand, timber—including the main-mast—and débris to a height of about 100 feet. A similar charge was placed in the forepart of the vessel, the explosion of which removed the whole of the obstruction except the sternpost, which was imbedded in the sand. A small charge placed beneath this brought it to the surface in fragments.

A Lecture Experiment.—To demonstrate the combustibility of the diamond and of the graphite, Mr. B. C. Woodward makes use of the arrangement described below.

The ordinary method is that of heating the diamond before the blow-pipe in a platinum spoon, and plunging it directly into an atmosphere of oxygen. This plan is, however, difficult of success; the diamond, if not very small, requiring several heatings to start the combustion; or, if very small, the phenomenon lasts but a second or two.

To meet the several objections, Mr. W.* takes a flask of about one litre capacity, and through the centre of the caoutchouc stopper with which it is furnished, passes two thin strips of brass, insulated from each other by a strip of bone (Fig. 1). Between the clamps c and d, which terminate the strips, is attached a thin strip of platinum foil, with a cup-shaped depression to receive the diamond. The upper ends of the brass strips, which emerge from the stopper, are provided with binding screws for attaching to a battery. In addition to the arrangement above described, the flask A is provided with two glass tubes, one of them, B, connecting with a reservoir of oxygen; the other, C, with a flask, D, fitted up like a wash bottle, and containing lime-water.

The oxygen is allowed to bubble through the wash bottle for a few seconds, to show that no turbidity is produced, and the binding screws then connected with a strong battery. The strip of foil holding the diamond becomes instantly heated, and the latter starts into combustion. The product of combustion passes into D, and indicates its presence by the milkiness of its contents. The apparatus is said to answer equally well for graphite.

Resounding Flames.—During the course of some experiments upon this attractive subject, Mr. H. Planeth has found that any flame whether that of a candle or gas flame, can be made to sing without the

* Chem. News, xxv, 127.

aid of a surrounding pipe or chimney, by simply bringing into its neighborhood the leg of a sounding tuning fork. He finds that, by approaching any freely burning flame in this manner, a loud tone is suddenly heard, though before the sound of the fork was hardly audible. If a strong gas flame is used for the experiment, the sound produced is at least as loud as that obtained on placing the fork upon a sounding box. The strongest sound is obtained upon placing the flame between the prongs of the fork.*

The author believes the phenomenon above described to be closely allied to that of the singing flames so well described by Tyndall and other experimenters. In the singing flames, however, the body of the flame is the material excitant of the sound waves, and the surrounding pipe, the resounding portion; while, in the present case, the fork excites the waves and the flame assumes the part of resonance.

On the Extinguishing of the Electric Light by the Approach of a Magnet.—By Prof. Edwin J. Houston.—Having occasion recently to set up a large battery for experimental illustration of the properties of the light of the voltaic arch, I noticed a fact which I believe has hitherto escaped observation.

The battery consisted of about eighty half-gallon cells; fifty-five were Browning's modification of the nitric acid battery of Grove. The negative element consists of sawed strips of very dense coke, the positive element of zinc, so arranged as to use both surfaces of the coke. The remaining cells were of the iron battery.

When first set up, the arch between the carbon electrodes measured fully two inches, while the flame frequently reached an equal distance above the upper carbon. The quantity of the current was very good, much better, in fact, than the size of the plates would have led me to expect.

The phenomenon to which I would call attention is as follows:

Wishing to show the well-known experiment of the rotation of the light by a magnet, I approached a compound bar magnet to the light, holding it with one end pointing directly to the arch, in a horizontal plane equidistant between the carbon electrodes. When the nearest end of the magnet was four inches from the electrodes, the light was instantly extinguished.

The regulator of the light which was employed is a form recently patented by Browning, of London. The carbon points are kept at a

* Pogg. Annalen, cxliv, 639.

constant distance from each other by the action of a small magnet worked by the battery current. Though inapplicable to small batteries, for the current I employed it gave a light admirable for its steadiness.

Thinking that the extinguishing of the light was produced by some cause other than the approach of the magnet, the experiment was repeatedly tried in a number of ways, until it was clearly shown that the cause could not be attributed to accident, but to the approach of the magnet.

Though I have failed to find any published notice of this phenomenon, it seems probable that it may already have been observed, as the conditions of the experiment would be almost exactly reproduced whenever the rotation of the light of the voltaic arch by the magnet was tried. Still it may be conceived that though the necessary conditions for success in this experiment have often been *nearly* reproduced, they have seldom, if ever, been exactly reproduced; for it was noticed that in no case was the light extinguished, unless the length of the arch was nearly as great as the tension of the electricity admitted; that is unless the electrodes were separated by nearly their maximum distance, consistent with the passage of the current. Were this condition not observed in all cases, the approach of the magnet produced no other effect than the rotation of the light, until it assumed a position in a vertical plane 90° from a similar plane passing through the magnetic axis of the bar. Then, again, another necessary condition is that both the tension and the quantity of the current be of a strength greater than that of the current on which the experiment of rotation is generally tried. I have experimented with flames when these latter conditions were absent, and although the rotation was observed, the extinguishing of the light was in no instance produced.

The compound bar magnet employed is formed of three bars, held together by brass screws. It is one foot long, one inch broad and three-quarters of an inch thick, and is not at all remarkable for the strength of its magnetism.

As to the cause of the phenomenon, I think it may be attributed to the tendency of the flame to rotate on the approach of the magnet. This might cause the extinguishing of the light in two ways; either by the irregularities on the surfaces of the carbon electrodes offering greater resistance to the passage of the current from some points than from others, or by the current being unable to pass through the greater

distance of the arched path, which is always assumed by the light on the approach of a magnet.

Another assumption, which, though perhaps not as simple as those already mentioned, at least as probable, is that on the approach of the magnet, there is a slight increase in the non-conducting power of the medium between the electrodes, produced by their polarization, and which, though always acting, can only manifest itself in a striking manner when the distance between the electrodes is near a maximum, and the tension of the current is exerted to its utmost in passing through the non-conducting medium.

This assumption of the polarization of the medium between the electrodes, and its consequently diminished power of conducting the current, seems to be somewhat sustained by the fact, that a powerful electro-magnet, in the form of a horse shoe, when approached, did not extinguish the light, although it produced rotation of the current, for we may conceive that the two poles, acting simultaneously on the medium, would neutralize each others effects.

I noticed, on several occasions, that the south pole of the magnet would not extinguish the light until it was approached one inch nearer than the north pole, namely, to within three inches of the electrodes. This, however, may have been accidental.

Dept. Physics, Central High School, Philada., April 12th, 1872.

Puddling by Petroleum.—It is asserted by the French technical journals that the experiment of using petroleum as fuel in the puddling furnace, which has been in progress at a large iron producing establishment during the past three months, has proved itself to be very successful. In point of convenience, efficiency and in the superior quality of the iron produced, it is asserted that petroleum affords the best fuel that has yet been employed.

The Passivity of Iron.—The item noted in our January issue, on the passivity of cadmium, in which Schönn's experiments were commented upon in their relation to the analogous phenomena presented by iron, was so extensively circulated as to warrant the presumption that a few remarks upon the latter case will not prove uninteresting. A brief recapitulation of some of the more striking properties of passive iron is herewith given.

It is well known that nitric acid in a diluted condition attacks the metals more energetically than when concentrated; the red fuming

liquid containing hyponitric acid and other nitrogen oxides is here excepted. With this fact some curious results are connected.

If iron is immersed in concentrated nitric acid, (the pure monohydrated acid answers best,) it will be momentarily attacked, as will be evidenced by the evolution of gas bubbles from its surface; this, however, very shortly ceases, and no further action is visible.

If a similar piece of iron is immersed in the same acid diluted with an equal bulk of water, chemical action at once ensues and continues with energy until either iron or acid is exhausted. So much for the relative oxidizing effects of concentrated and diluted acid. Let the experiment be varied as follows.

Prepare two glasses, the one containing the monohydrated, the other the diluted, acid. Plunge into the latter a rod of iron, which will be vigorously dissolved. Remove it now into the first glass, and the dissolving action will almost instantly cease; return it after a few moments to the diluted acid, and it will remain there entirely unaffected.

The contact with the concentrated acid appears, therefore, to have so altered the surface of the metal as to render it entirely indifferent to the presence of chemical agents, to which before it was highly sensitive. Without implying the possibility of the transmutability of the elements, (which, it may be incidentally remarked, seems far less absurd with our present knowledge than it did twenty-five years ago,) it really appears that the surface of the altered iron has acquired the properties which render it more electro-negative than normal iron; so that if the two are brought in contact, immersed in an exciting liquid, they will generate a galvanic current; an effect which is universally regarded to predicate the contact of two unlike elements. The liberation of hydrogen *in statu nascendi*, on the surface of the altered metal, appears, however, to have the effect of bringing it back again to its normal condition; for the current shortly ceases to flow. To illustrate the foregoing, the following experiment will suffice.

Let the altered rod, which remains unaffected in the diluted acid, be touched for a moment with a rod of iron which has not previously been immersed in concentrated acid, and it will instantly be attacked; or, dip such a rod, after immersion in a mono-hydrated acid, into a copper salt solution, and it will be found to remain entirely free from copper—(a proof, it would seem, that the altered surface is electro-negative even to copper); remove it now and touch it for a moment with a piece of normal iron, and it will instantly coat itself with copper,

reducing the thin film of the salt remaining on its surface. Upon the explanation above mentioned, which may or may not be correct, the contact of the two pieces of metal generates an electric current; hydrogen is liberated upon the negative or altered iron, converting it again to its ordinary state. The moment this takes place, the diluted acid, in the first case, seizes upon it; or, in the second, the copper salt is reduced.

For want of a better explanation for the curious facts here noted, that offered above must answer. In conclusion, it may be remarked that a very cheap and efficient form of battery—the Maynooth iron battery—the outer cell of which consists of a vessel of passive iron containing concentrated nitric and sulphuric acids, has been constructed by taking advantage of the indifference to the action of acids which may so easily be established in iron as above described.

Bibliographical Notices.

Nystrom's Pocket-Book of Mechanics and Engineering, eleventh edition, revised and enlarged with original matter, has been received from Lippincott & Co.

This well-known pocket-book has now been increased to over 500 pages, containing much valuable matter of original conception, and the great variety of subjects, in form of tables and formulas, with practical examples, are well arranged.

Dynamics, pages 262, 310 and 311. The author classifies dynamical terms as follow: *Force, motion* and *time* are simple physical elements; *power, space, work* and *momentum* are functions of the aforesaid elements. This, he maintains, are all the terms necessary in dynamics. A list is given of confused dynamical terms, including *moment of inertia*, which he proposes to abolish.

Examples are given for the dynamics of fly-wheels, in which the term *moment of inertia* ought to occupy an important function, but does not appear in the formulas or calculations. *Moment of inertia* is a long-established term in dynamics, but is disregarded by Mr. Nystrom, and, however right or wrong he may be in the philosophy of dynamics, his reasoning is well worthy of attention.

The formulas for the flow of water in bends of pipes, page 342, appear to be new. The barometrical tables for the measurement of

heights, in English and French measures, pages 364 to 370, are very complete, and have been arranged by the author from actual practice in the Andes.

Logarithms of trigonometrical functions for every minute of a degree, or for every four seconds of time, also the eight trigonometrical functions for angles, expressed either in degrees or in time, as may be required, are the best arranged tables we have seen.

The author gives an original illustration, with formulas, for the expansion of bodies by heat, at and near the temperature of fusion, page 384.

Properties of inflamed gunpowder, and its dynamics in heavy ordnance, page 393. The author thinks that the charge ought to be so arranged that a slow powder is first ignited, then a quicker, and at last the quickest, by which, he says, the gun would be less strained and greater effect in the projectile secured.

Properties of water and steam in relation to heat, with formulas and tables, will be found extremely useful.

Formulas for the ultimate strength of flues for external pressure to collapse, are given on page 425, in which Mr. Nystrom says that the strength is inversely as the *square root* of the length, whilst Mr. Fairbairn has determined by experiments that the strength is inverse simply as the length. This is an important question in the strength and safety of steam boilers: both cannot be right.

On page 428, radiation of heat from steam pipes, boilers and steam cylinders, is an important article for the economy of steam and fuel.

On page 446, on the parabolic construction of ships, is very much the same as has appeared in the "Journal of the Franklin Institute," only that the formulas are more simple and less in number, and the tables are more complete. A formula is given on page 448 by which, the author says, any form of a ship can be recorded, and by which a ship-builder, familiar with the parabolic method, can construct a ship of a definite form. It appears that this parabolic method is a positive rule for the construction of ships of any form.

The properties of various explosives used for blasting are described upon page 473.

The additions to the eleventh edition are very appropriate, and greatly increase the usefulness of this standard book of reference.

Civil and Mechanical Engineering.

INTEROCEANIC COMMUNICATION ACROSS CENTRAL AMERICA.

By Prof. J. E. Nourse, U. S. N.

(Continued from page 383, Vol. LXII.)

The line of our narrative, which will offer a brief sketch of each important route, may here give place to some tabulated lists. The first of these is invested with additional interest by its association with the name of one so well known through successful labor in the varied branches of useful research.

I. Humboldt's Nine Routes.

1. River Columbia, to connect with Peace River, N. A.
2. Rio Colorado, to connect with Rio del Norte, Texas.
3. The Tehuantepec line.
4. The Nicaragua line.
5. The Panama line.
6. Cupica Bay and Rio Naipi with the Atrato.
7. The (supposed) Raspadura Canal: Rio Quito with the Pacific.
8. Rio Guallaga to connect with the Para, Brazil.
9. Gulf of St. George with W. coast of S. America.

A curious map, "*assembling these*," as Humboldt's translator says, will be found in Vol. 2d of "New Spain," London edition, 1822. In his later days, Humboldt rejected all of these except those numbered above from 3 to 6, inclusive. He steadily urged a true and thorough exploration of Darien. It will be noted that his eye was on the whole Western coast of North and South America.

After the lapse of more than half a century, thorough surveys of the most Southern portion of this Isthmus have been made:—In 1852 by J. C. Trautwine, C. E., of Philadelphia; in 1853 by Messrs. Lane and Porter; in 1854 by Mr. Kennish; in 1858 by Lieut. Michler, U. S. A. and Lieut. Craven, U. S. N.; and, in 1870–1871, by Com'r T. O. Selfridge, U. S. N. The report of the last named officer now being made up for the Navy Department, offers promise of our realization of Humboldt's expectations of success through the Cupica line, [No. 6 of the above.]

Our second table will be taken chiefly from the "Annales des Voyages" of M. Malte Brun *fils*.

II. Projected Routes across Central America.

A. *Projected Canals.*

I. 1. *Tehuantepec:* Coatzacoalcos and Chicapa.

II. 2. Honduras. [Canal found impracticable.]

III. *Rio San Juan de Nicaragua; L. Nicaragua.*
- 3. Rio San Carlos, Gulf de Nicoya.
- 4. R. Nino: Tempisque. G. de Nicoya.
- 5. R. Sapoa, Bay Salinas.
- 6. R. San Juan del Sur.
- 7. Brito.

Lake Managua,
- 8. Rio Tamarinda.
- 9. Port Realejo.
- 10. Bay of Fonseca.

IV. *Panama.*
- 11. Gorgona, Panama.
- 12. Trinidad, Caymito.
- 13. Navy Bay. R. Chagres, R. Bonito, R. Bernardo.

V. *Darien.*
- 14. San Blas, R. Chepo.
- 15. Bay of Caledonia, Gulf of San Miguel.
- 16. Rivers Arguia, Paya, Tuyra, Gulf of S. Miguel.
- 17. *R. Napipi, Cupica.*
- 18. R. Truando, Kelley's I.
- 19. R. Tuyra, Gulf of Uraba or R. Atrato.
- 20. *Bay of Cupica, by an East line to the mouth of the Napipi, and through Atrato R. to G. Darien.* — (*Commander Selfridge, U. S. N.* 1871.

B. *Projected Railroads, or Carriage Roads.*

1. Coatzacoalcos to Gulf of Tehuantepec.
2. Bay of Honduras to Gulf of Fonseca.
3. Rio San Juan, Nicaragua, Managua, G. Fonseca.
4. Gorgon Bay, or Pim's Bay, N. of Greytown, Realejo.
5. Gorgon Bay, San Juan del Sur.
6. Port Limon and Caldera on Nicoya Gulf, Costa Rica.
7. Chiriqui Inlet, Golfo Dolce.
8. *Colon,* (*Aspinwall,*) *and Panama,* (R. R. finished 1855.)

A glance at the map shows this classification to be in geographical order from North to South.

Other (*paper*) routes might have been included above; but their impracticability and, in some cases, falsity, will be occasionally shown in the sketches of the chief lines on which we now enter.

THE TEHUANTEPEC ROUTE.

Topographical View of the Isthmus.

Mr. J. J. Williams, Chief Assistant of Gen'l Barnard's survey—made in 1850, for the Tehuantepec Railroad Co. of New Orleans—presents, in his report, a general topographical view, which is here chiefly used.

The only other survey worth naming, (that recently made by "the Tehuantepec and Nicaragua Expedition, Capt Shufeldt, U. S. N.,") has somewhat modified the statements of the first named report.

Mr. Williams says:—"The Isthmus of Tehuantepec is that part of Mexican territory which lies between the Gulf of Mexico and the Pacific Ocean where the seas approach each other nearest, within Mexican limits. The narrowness of the Isthmus and nearness of a transit here to the chief ports of New Spain, Vera Cruz and Acapulco, made this route one of the earliest for exploration. From the mouth of the Coatzacoalcos in 18° 8′ 20′ N. latitude and 94° 32′ 52′ West longitude to the harbor (?) of La Ventosa, on the Pacific, in 16° 11′ 15′ N. latitude and 95° 15′ 40′ West longitude, the distance in a direct line is 143½ miles, nearly due North and South." (The coast line on each ocean is thus nearly East and West; the basin of the Coatzacoalcos is, therefore, open to the "Northers." "Tehuantepec" is, itself, (as was noted by Humboldt,) the name of an impetuous N. N. Easter.)

"The Isthmus may be properly said to comprise three main divisions, more or less distinct in their general characteristics,—their topography, geological formation and salubrity. The first embraces the country extending from the Gulf to the base of the Cordillera; this may be called the Atlantic plains and is the least healthy. The second comprises the more elevated districts in the central part; these are said to be healthy. The third includes the level country bordering on the ocean or the south, and known as the Pacific plains, warmer and less healthy than the hill country."

The first division comprises a belt of country of some forty or fifty miles in breadth, of rich alluvial basins, the principal of which is that of the Coatzacoalcos, draining the northern slope of the Cordilleras. On the West of this river is the Tuxtla range of mountains, the chief peaks of which are of considerable height; and on the East of these

is Mt. Tecuanapa, surrounded by extensive plains, and having an elevation of 1200 or 1500 feet above the level of the Gulf. But with these and a few other exceptions, the country of this Northern division presents the appearance of a broad plain, entirely covered with dense forests.

"The second division, extending from the Jaltepec river on the North to within twenty or twenty-five miles of the Pacific coast, and comprising a strip of some forty miles in breadth on the west, and widening out towards the east, presents a great diversity of feature. The immense chain of the Cordillera here traverses the country; but instead of lofty volcanic peaks elsewhere found, there is a sudden depression of the range in its passage across this Isthmus at a point directly in the line of shortest communication between the two oceans, yet the elevated spurs and ridges traversing this country generally in an east and west direction, interpose serious obstacles.

"By a narrow opening or gap in the mountains we descend suddenly from these elevated table-lands to the Pacific plains, which form the southern or third division. These average about twenty miles in breadth from the base of the mountain to the Pacific coast, and descend on the meridian to the lagoons, presenting a uniformly gentle slope towards the sea. They are traversed by eight rivers, which discharge the drainage of the southern slope, seven of which empty into lagoons; the eighth, or Tehuantepec River, comes down by a northwesterly direction, and, passing by the city of the same name, discharges itself directly into the sea at the Bay of Ventosa. This Bay is formed by an indentation on the coast and the projection of the Cerro Moro on the West. It is but partially sheltered from the North winds by low ranges of hills from three to four miles distant.

"Of the streams watering the northern slope of the Isthmus, the most important by far is the Coatzacoalcos. It drains a large extent of country, and furnishes a natural channel for effecting in part the communication between the two oceans. Its mouth is about fifteen hundred feet in width, with a varying depth, the greatest being thirteen feet. The tides are not strong on this part of the Mexican coast; but when the heavy northerly winds blow, the waters of the river are heavily backed up, giving a sensible increase of depth on the bar."

Cortez, in an official dispatch to Charles V, speaks of the importance of this harbor as the best then to be found on the Gulf of Mexico. Giving the results of a survey made by his order, he says, "They found two and a half fathoms of water at its entrance in the shallowest part, and ascending twelve leagues, the least found was five fathoms."

These soundings in 1520 gave about the same depth over the bar at the mouth of the river as that which we now find. Mr. Williams considers this as proof that the material of which the bar is made does not change its position; there is promise, therefore, he says, of security to any work for deepening the channel at this point.

It appears from the elaborate Report of Mr. Williams, that the two harbors which should be the termini of either canal or railroad on this line, have but moderate claims for our regard, at least in their present state. They admit, however, of very satisfactory improvement at perhaps moderate expense. Mr. Williams says positively in regard to the Coatzacoalcos, "The fact of there being no delta at the mouth of the river, and the constancy of the depth upon the bar, which has remained unchanged, according to the history of the country, nearly three centuries, proves that it has attained its *regimen*, and indicates that any improvement by deepening the channel may be relied on as permanent." Of La Ventosa, on the Pacific, he says, "it can be used in its present condition in the same manner as Panama, by employing lighters." Is not the name, "La Ventosa," however, a historic record against it as a harbor? Would those who frequent this coast accept this parallel with Panama? Are not additional obstacles and yet more serious ones to be found in the length of the route, the heights to be overcome by numerous locks, and the want of a sufficient feeder for a canal? Such does not seem to exist within any reasonable nearness. This last named fact, with other discoveries valuable in the full and final solution of the problem, will be found in the notice of the U. S. Tehuantepec Expedition of 1870–71, at the close of this article.

Attempts to establish Communication.

In 1551, Lopez de Gomara, the author of the History of the Indies —a work highly praised by Humboldt—proposed a union of the oceans by *Tehuantepec*, Nicaragua and Chagres.

In 1745, prominent persons of Oaxaca memorialized the Viceroy of New Spain for a canalization of the "Guasacoalcos," and a continuation by the Sarabia. It has been already noted (p. 12) that this memorial was the occasion of an edict from Spain forbidding the subject to be again mentioned.

In 1771, occurred the following singular excitement. Among the artillery at the fortress of San Juan d'Ulloa, were found cannon evidently cast at Manilla. But as the Spaniards, up to this time, had never doubled either cape to reach the Phillipines, yet had traded

largely from Acapulco directly across the great sea, it was at once said these cannons must have crossed Mexico by ascending the Chimalapa, and, after being dragged over the "*divide*," by descending the Guasacoalcos. At this idea public sentiment was excited. For if such heavy ordnance had thus been brought over, was it not proof that here communication could be opened up? The Viceroy, Don Antonio Bucareli ordered a survey to be made by Cramer and Corral, the former being an engineer as well as the Governor of d'Ulloa. Their work must have been a reconnoisance only. It does not appear that they made any levelings, or determined any elevation. They pointed out that a good harbor failed the route on the Pacific side, and appear to have confirmed the feasibility of improvement of the mouth of the "Guasacoalcos." It can scarcely be believed that they reported the canal practicable without locks, or inclined plains.

Such reports, with others of like character following them, gave a good name to this Isthmus during the rest of that century. In 1814, the Spanish Cortes listened to the proposition of a Mexican Deputy, Señor Alaman, and decreed the construction of a canal. The political distractions immediately following, and the independence of Mexico, left the government of Spain without power to promote the scheme.

In 1824, Col. Juan de Orbegozo, an officer of high reputation, was ordered on an exploration, which he began in 1825, and in which he endeavored to measure the height of the sea level by means of the barometer. His instrument, however, proved to be unreliable. Orbegozo reported the Coatzacoalcos as navigable for sea-going vessels ten leagues into the interior; that the Chimalapa, looked to as the southern section of a canal, was navigable in the rainy season only; that there was a deficiency in the want of a feeder, and that the seaport of Tehuantepec was shallow and open to the Northers. He concluded his report by affirming that the canalization of the Isthmus of Tehuantepec remains a *problematic* and *gigantic* work; but he regarded it an easy work to offer up a good route of inland communication between the lagoons of Tehuantepec and the Guasacoalcos.

Garay's Exploration.

In 1842, Santa Anna, president of Mexico, made a liberal grant to Don Jose de Garay, in furtherance of his scheme of opening up a route across the Isthmus; a primary condition requiring him to cause a reliable survey to be made. Garay employed eminent engineers, at the head of whom was Señor Gaetono Moro.

Moro published his report in 1844. It attracted attention both in this country and abroad. The difficulties of the route, although partially dealt with by his officers, caused Garay himself, at an early stage, to abandon the scheme. Moro's report has been regarded as in some degree promising, in respect of the important point, the supply of a feeder, *until* the thorough survey by our Government in 1870. The following notes will show the estimate held of Moro's work at the time of his report. Mr. Henry Wheaton, U. S. Minister at Berlin, deeply interested by his association with Humboldt in the plans for interoceanic communication, made favorable notice of it in an elaborate discussion which formed part of an official communication from the President of the United States to Congress. Vice-President Dallas published an extended discussion favoring this route. Vide *Journal of the Franklin Institute*, Vol. XIV, 1847.

In the instructions to Mr. Trist, U. S. Commissioner, in 1847, for a Treaty of Peace with Mexico, he was authorized, in extending the boundaries of the United States, to offer thirty millions of dollars in place of fifteen, "provided the right of passage and transit across Tehuantepec be secured." The Mexican Government "absolutely denied or refused to concede any such right." This, it has been affirmed, "was wholly based on the ground of its having made a previous concession to Garay." Is it not also probable that the refusal was caused by the fact that the concession to the Government of the United States, as such, would have seemed to compromise the security of the Isthmus? for concessions have not been withheld by Mexico from companies or individuals. Under the ever changing governments, at least three liberal grants, in recent times, have issued. The grant to Garay virtually fell into the hands of Messrs. Manning, Mackintosh & Hargous, who associated themselves with a company in New Orleans, and sent Major (now Maj. Gen. Barnard,) with Williams for his assistant, to make the survey quoted in the outset of this paper. Finally, in 1869, a new Tehuantepec Railway Company, organized in New York, (Mr. Simon Stevens, President,) have recently sent a surveying party into the field, and are prosecuting their enterprise.

Latest Survey and Results.

Since the preceding sketch was made, the report of Capt. R. W. Shufeldt, U. S. N., of the Tehuantepec and Nicaragua Surveying Expedition, has been communicated to Congress. It will be found to be an honest, impartial and able account of the Isthmus. The officers

of the Navy in charge were Captain Shufeldt, Lt. Commanders Remey, Bartlett, Farquahar and Cooper; Surgeon, I. C. Spear; Civil Engineer, E. A. Fuertes. The following notes only are given from the Report. Captain Shufeldt's memorandum, submitted to the Navy Department before organizing the expedition, embraced the important ideas:—that a ship canal through some pass of the Isthmus "is a necessity for the present and prospective commerce of the world;" that America should select that route which, satisfying interoceanic demands, will also best develop American trade; that a route from some port in the Gulf of Mexico should have preference, because the American Navy, by using Key West and the Tortugas as their base, can always hold the Gulf and its transit, since the channels to it are, in the aggregate, not more than 200 miles wide; and that the Tehuantepec route is the shortest for us, offering a gain in distance of 1350 miles over Panama, and permitting a steamer to load on the Mississippi and discharge her cargo in twelve days at San Francisco.

The Expedition had for its plain purpose to test the validity of Garay's survey, in which Moro gave the height of Tarifa, the summit level, at 680 feet, and asserted the entire feasibility of providing a feeder for a ship canal by the junction of the Chicapa and Ostuta rivers; other streams proposed as feeders by Mr. Williams were also to be examined.

The Expedition reached Minatitlan early in November, 1870, and remained on the Isthmus until the following April. The Mexican Government promptly acceded to the wishes expressed by the United States; and also appointed a Commission of their own, which worked harmoniously with Capt. Shufeldt's party. President Juarez also provided a battalion of 600 men for their protection in the disturbed districts. The work of the Commission was executed with fidelity and with full thoroughness to demonstrate—

(1.) That the plan of Moro's to join the Chicapa and Ostuta is impracticable; and that if the junction were effected, the supply of water would be insufficient; nor can a supply be had from the streams in the vicinity of Tarifa or Chivela.

(2.) That the summit level, Tarifa, is 754 feet.

(3.) That the bar at the mouth of the Coatzacoalcos is deepening by natural causes, and can be easily dredged at moderate cost, and the harbor made one of the best on the Gulf, and—

(4.) That the Corte or Upper Coatzacoalcos can be made a sufficient

feeder, and, on the Pacific side, the Bay of Salina Cruz be also made a good harbor.

The line suggested for a canal by Capt. Shufeldt starts in the Coatzacoalcos at the Island of Iacamichapa, running through the river valley to the divide at Tarifa, and through that pass to Salina Cruz, the sea-port of Tehuantepec. Its length must be about 144 miles, requiring about 140 locks; and, for the line of the Corte feeder, a tunnel of three miles, with a deep cut of 22 feet, to reduce the summit level. The feeder would be 27 miles in length. The canal to have a breadth of 162 feet at the surface and 60 feet at the bottom, and a depth of 22 feet.

The report makes no estimates of total cost. It presents a reliable summary of disadvantages and of advantages; the most gratifying points in it being the promise of good harbors as termini.

The additions made to our knowledge of the present social and political condition of this unhappy country, of its volcanic character and of its unhealthiness, have all an important bearing on the practicability of executing a work which Capt. Shufeldt frankly says would call for a treaty, not a private concession, and for national resources and national guarantees. His report, completed by Lt. Commander Bartlett, gives just occasion for honorable tribute to the U. S. Navy and the Government of our country.

The Report of the Engineer, Mr. Fuertes, contains the following encouraging statement:

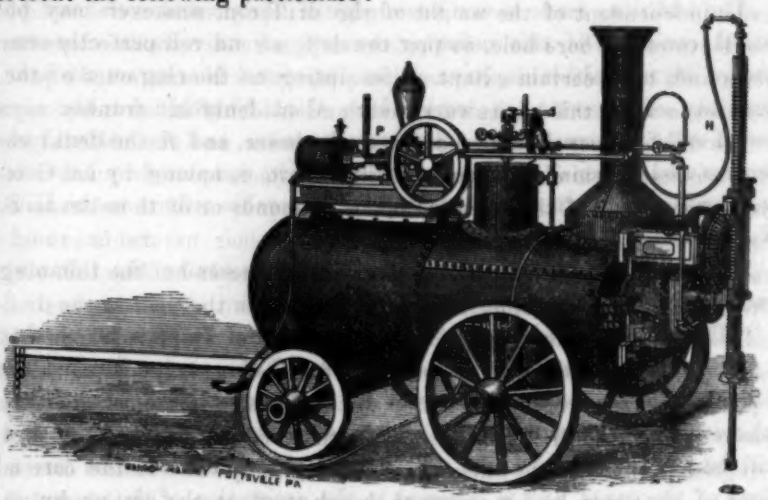
"The data obtained from our explorations and surveys prove that a ship canal is practicable on the Isthmus of Tehuantepec, because the difficulties to be encountered are of the ordinary type, or such as are inherent to works of a similar nature, with the difference that they will be met on a large scale. This fact is due to the assumed dimensions of the canal, and is inherent to the conception of the project in whatever part of the world it might be located."

Capt. Shufeldt himself, in his preliminary report to the Secretary of the Navy, April 18, 1871, says: "It is to me a source of great gratification to be able to say that an interoceanic surface canal of any necessary dimensions may be constructed across the Isthmus. * * * I make no estimate of its cost. It will be dear in point of money; cheap in point of American progress, peace and prosperity." —[New Route of Commerce, by Mr. Simon Stevens, Pres. T. R. R. Co., London, 1871.]

THE DIAMOND ROCK DRILL.

By John Warner, A. M.

Engineers and mechanics are acquainted with the process of boring metals with rotating drills made of hardened steel, but boring the hardest rocks with rotating drills set with diamonds for cutters is a recent invention which, although in use several years, will, I think, have the interest of novelty for most of the readers of the Journal. The invention is due to Prof. Leschot, a French engineer. It was used in completing the Mont Cenis Tunnel, and was favorably reported on by a commission at the Paris Exposition of 1867. The Pennsylvania Diamond Drill Company is now engaged in manufacturing and operating the Diamond Drill. By the kindness of M. H. Smith, Esq., of Pottsville, the Company's Resident Superintendent, I am enabled to present the following particulars:



The cut represents a Portable Steam Rock Drilling Machine, suitable for boring artesian wells, or test-holes in prospecting for coal or minerals; it weighs about 6000 lbs. Other machines, constructed on the same general principles with this, are made of various forms and sizes, for various kinds of work, as for quarrying, sinking shafts, mining and tunneling: these machines may be operated by steam or by compressed air.

Returning to the cut, the boiler is immediately recognized, and the machinery which operates the vertical drill is bolted against the end of the boiler.

This machinery consists of two oscillating steam cylinders, C, of six inches diameter and six inches stroke, working the same crank shaft; other details of the steam engines need not be noticed here. By a series of mitre wheels and other gearing, the revolution of the crank shaft produces the rotary motion and downward feeding of the vertical drill rod, or its speedy withdrawal, when desired, from the bore hole.

The drill rod is made of iron tubing, especially prepared, screwed together, from time to time, in sections, as the drill descends into the rock.

The drill rod passes through a larger tube, about ten feet long, having a screw thread upon the outside. This tube produces the so-called automatic differential and frictional screw feed, by means of which the feed motion and the pressure of the drill upon the rock are made independent of the weight of the drill rod, whatever may be the depth of the bore hole, so that the drill is rendered perfectly sensitive and, to a certain extent, self-adapting to the character of the rock, even when this varies extremely and suddenly in hardness.

The drill proper is screwed fast to the lower end of the drill rod. It is a metallic thimble, about four inches long, having a number of diamonds, either of the so-called black diamonds or of those translucent or partially crystallized, or of both, in their natural or rough state, firmly imbedded in the annular face of one end of the thimble; a female screw in the other end suffices to attach the drill to the drill rod. As the drill descends, a cylinder or core of stone is left standing inside of the hollow drill rod: a self-adjusting wedge is placed in a groove inside of the hollow drill; this wedge allows the core to pass freely up into the drill rod, but seizes the core and breaks it off and brings it to the surface when the drill is withdrawn. If the core is very large, it may be necessary to break it off at the bottom by an ingenious system, of which we shall not give details; frequently the core is broken by natural cleavages of the rock. The cores thus taken out, from time to time, give a perfect record of the lithological formations through which the drill has passed. It is also possible to use drills which make no core, cutting the hole in its whole diameter; but we continue to speak of the hollow drill.

An indispensable appendage is yet to be mentioned: this is a steam force-pump, P, here seen on top of the boiler. This pump draws a supply of water from any convenient reservoir, by means of a rubber hose, and in a similar manner forces the stream, through a swivel joint,

in at the upper end of the hollow drill rod, and thus to the bottom of the bore hole, where it moistens the rock, keeps the drill cool, and then ascends on the outside of the drill rod, carrying upwards the fine material or cuttings into which the rock is reduced by the diamonds set in the drill.

The principal parts of the machine above mentioned are, then, 1st, the boiler; 2d, the steam driving machinery and feed gear, with the drill-rod and drill; 3d, the force pump and stream of water. These parts may be connected with a vertical boiler, or they may be separated and placed at a distance each from the others, according to the nature of the work. It should be observed that the drill rod and feed gear can be so arranged as to permit boring in any desired direction, with convenient modes of shifting the direction at pleasure; and the same freedom of application may be obtained with compressed air for a motive power.

The speed of boring depends much upon the nature of the rock, varying, for a two-inch hole, which is suitable for test-holes, from four feet per hour, in hard rock, to ten feet per hour in sandstone and slate, with a rotary speed of three hundred revolutions per minute.

In the Pottsville region holes have been bored, in hard rock, as large as nine inches in diameter.

These machines are recommended by General H. Pleasants, Engineer of Mines of the Philadelphia and Reading Railroad Company, under whose direction they are now in use, near Pottsville, in sinking deep shafts upon coal lands belonging to that Company.

The speed with which the work of shafting and tunneling may be prosecuted, and the regularly cylindrical shape of the holes—an important matter in blasting—give these machines advantages over all others yet known for the same purposes.

MERRILL ON IRON TRUSS BRIDGES,

By Charles F. Johnson, Jr.,
(Engineer for the Kellogg Bridge Company.)

Although Colonel Merrill's work has been before the profession for some time, a few words on various subjects suggested by it may not be unseasonable. The subject of Iron Bridge Building is becoming so important, that any contribution to our knowledge of the economical distribution of material in an iron truss is valuable. A thorough and analytical work, like that of Colonel Merrill's, must therefore be

welcomed by every honest builder, though they may disagree with some of his positions. All can, however, endorse the following quotation:

"The effect of competition is such that many bridge builders, while professing to use 5 or 6 as their factor of safety, really use a much smaller number. It is to be hoped that every railroad engineer will so familiarize himself with the theory of bridge building, as to detect and prevent any such frauds on the companies and the public."

That portion of the book which is devoted to an examination of Hodgkinson's and Gordon's formulæ, and the graphic representations of their results by curved lines, is especially interesting. There is nothing more instructive than a graphic illustration of a law, and the thanks of all members of the profession are due to Colonel Merrill for his conscientious labor. A series of careful experiments on struts of the various sections we must necessarily use when wrought iron is the material employed, would leave nothing to be desired in our knowledge of this important subject. These are generally hollow squares or H sections, and the formula involving the radius of gyration has never received the seal of practical test. There is no form of truss where the strains are so fairly divided among the various members, as that with pin connections top and bottom. It is impossible to distort it by ignorant or careless adjustment. But since the pressure on the struts is applied through the medium of the pin, they partake of the nature of square and of round end pillars, square in a plane at right angles to the axis of the bridge, and round in a plane at right angles to the axis of the pin. What is the most advantageous section for struts in this condition is a point which remains to be decided. Probably it would prove to be a hollow square with three times as much material on two opposite sides as on the other two. It certainly would not be a cylinder.

As a practical question, Colonel Merrill has put his panel load for a locomotive too low—35,200 pounds. There are engines that throw from 25 to 30 tons on the drivers in a space of twelve feet. Nor is it safe to assume that only one engine could be on the bridge at a time; two are not unfrequently coupled. However, as his figures are assumed for the purpose of comparison merely, and as his weights for tender cars and structure are high, the point is of minor importance. His weights and method of computing strains are, we believe, those adopted by S. S. Post, the father of scientific bridge building in this country.

In his general discussion, Colonel Merrill says, "It is a well-known principle of mechanics, that any body acted upon by a system of forces in equilibrio, is affected by new forces as if the original forces did not exist."

This is a principle of dynamics rather than of statics, and strictly applies to a system of bodies free to move in space. Like all general principles, it must be applied with strict reference to its limitations. When one of the forces is the resistance of a stone abutment, capable of indefinite increase, and all of them are compelled to act in fixed lines through a medium so elastic as iron, the legitimate inferences from the principle are to a great extent controlled by these circumstances.

A book lies on the table before me in equilibrium between gravity and the resistance of the table. I toss another on it. If gravity and the resistance of the table did not exist, the books would move, but the resistance of the table meets the new demand, and the books remain at rest. This rude illustration may serve to show that it is possible to draw an incorrect inference from a general law.

From the principle above laid down, Colonel Merrill deduces the rule that equal weights, similarly situated on a bridge, balance one another, and assumes that the effect of the moving load is exactly the same as it would be if the bridge were devoid of weight, since the panel load of the structure and track applied at the feet of the several ties' balance one another and act as a set of forces in equilibrium. The practical result is that he finds counter-strains where none really exist, *i. e.*, in the counters nearest the abutments. That these counters are not affected by the moving load, follows from the principle that a strain in a counter and a tie which forms the other diagonal of the parallelogram cannot exist at the same time, and the permanent strain on the tie from the static load is greater than the strain on the counter from the moving load. Any cause which tautens one diagonal slackens the other. I speak of course of strains produced by extraneous causes, such as the load. Strains caused by screwing up the rods, affect each of them. Again, many trusses are built without these counters, for instance, the Pratt-Whipple; in this no counter is run to the foot of the first panels. A moment's consideration will show that if either of these points descend, every other point on the bridge must rise. The entire weight of the bridge balances a moving weight applied at these points, and experience proves that they are unyielding, unless the bridge is very light.

There is another consideration which militates against the theory of balanced weights. A double triangulation truss consists of two single triangulation trusses with a common top and bottom chord; weights on the floor beams of one system can have no effect on the ties, struts and counters of the other. Each system carries one half of the load independently, and the strains must be separately considered. If there is an uneven number of panels, the systems are not symmetrical longitudinally. Take a Pratt-Whipple over-grade, for instance, in which each truss can be separated into two systems.

It is evident that there can be no balancing of equal weights in this case, for the weights are not equally distant from the abutments. This consideration also shows that the common method of computing the strains in a double cancellated truss with an uneven number of panels is erroneous. The tie, instead of carrying one panel load of the static weight, carries only $\frac{6}{11}$, and the rod, instead of doing no duty, carries $\frac{8}{11}$ of the static load, and so on for the others. The method of equal moments avoids the error.

However, admitting that I am correct in supposing that the theory of balanced weights is misconceived by the author, the practical effect is of little consequence. The counters, which are invaluable for the purpose of lessening the amplitude of the vibrations of the structure, should always be made larger than this theory would call for.

I have not had time to give the remainder of Colonel Merrill's book the careful reading it deserves. It would seem strange, however, that he should make the top chord of a Linville Truss twenty-five feet high, only ten per cent. lighter than the top chord of a Post Truss, eighteen feet high, same span. Experience would suggest that there would be at least twenty-five per cent. difference. If there is any economy in the Post Truss, it is in the web and not in the flange of the girder. The top flange is in general a function of the span, the load and the depth, and the compressive strains in it cannot be much affected by the connection between it and the bottom flange. The weight of different trusses can be safely compared only by making out the bill of iron just as it would be ordered, and their stiffness by running a train onto them and measuring the deflection. Without correct theory we grope in the dark; with correct theory alone we are liable to stumble; with correct theory and carefully tabulated experiment, we are absolutely sure of our ground. Theory controls within the limits set by practical considerations, but the theory which makes the top chord of a high truss so little lighter than the top chord of a low truss, would

find some difficulty in making the low truss as stiff as the high one. There is nothing in which the practical common sense character of American engineering shows itself more distinctly than in the universal adoption of deep trusses.

ON FEED-WATER TO STEAM BOILERS.

By Ign. Hahn.

(Continued from Vol. LXII, page 405.)

First of all, permit me to allude to some inaccuracies, which I observed on reading my former article, viz.:

On the table of analyses, in analysis No. 4, the Silica is omitted, amounting to 0,13000; further, in No. VI, the free Sulphuric Acid should read 1,66200, instead of 1, as stated there, and finally let me add No. VII, as follows:

Chloride of Calcium, .	0,11730
Sulphate of Lime, . .	0,94350
Carbonate of Lime, . .	0,72232
Carbonate of Magnesia, .	0,35072
Sulphate of Iron, . .	0,90250
Silica, ...	0,01500
Organic matter, . .	4,68300
Residue left on evaporation, . .	8,56500
Mechanical impurities, likely coming into boiler, ...	63,17000
Total sediment, . . .	71,73500

The mechanical impurities are added to the total chemically combined matter, under the presumption that the water is forced from the brook or creek directly into the boiler. Of all the 7 analyses, the water as represented by analysis No. I is the best; but No. II being easier of access, its impurities in quality and quantity still countable as exceptionally good or favorable ones, the latter will be used for the works of Boston Franklinite Company, in preference to No. I; the more as the Franklinite ore crushing and washing establishment of the Passaic Zinc Company, situated about one mile further up the creek, worked to their utmost capacity, at the time the water was taken for analysis, from which source it receives very likely a considerable part of its chemical and much mechanical impurities.

Speaking now of the Roaring Brook water, analyses of which are

shown by No. III to VII inclusive, it is obvious that No. III is superior to all, next comes No. IV, VII, V, and last No. VI; No. IV and VII are such as at present supplied to the city of Scranton for domestic purposes, by the Scranton Gas and Water Company, and is also used in a number of steam-boilers.

Owing to the larger amount of sulphate (of lime and iron) in the water from this place, it does not behave satisfactory in the boilers, inasmuch as the sulphate of lime has a tendency to attach so strongly to the iron of the boilers, that it can be removed only with great difficulty; blowing off by itself will carry away but very little of it, while the sulphate of iron is liable to slowly attack the iron of the boiler.

The sulphates do not appear to be in large proportion, but when compared with the total foreign matter, as chemically combined, are very large, being nearly 40 per cent. of the whole; thus but very little mixed with them to prevent their close contact with the iron all over. Still worse is the water from analyses V and VI, where free sulphuric acid is to be contended with, acting very injuriously upon the boilers.

Boilers, where this water is made use of, are being blown off partially from 6 to 8 times every 24 hours, and notwithstanding that the total impurity of the water in its natural state cannot be called excessive, yet each time it streams forth in an extremely muddy condition, and of a color plainly showing the destructive part it has played on the boiler-iron. This water, or rather the sulphuric acid in it, first commences eating up the edges of the rivet heads and the ends of the sheets, causing very frequent repairs.

This kind of injury is not so dangerous if well looked after, because it shows itself by water leaking through; it is different when it commences to attack the plain sheet, thus weakening the strength of the boiler to withstand the pressure of the steam within; which occurrence is the more detrimental, because it is not so easily detected, and occasionally may lead to an explosion ere the attendants of the boilers become aware of the existing peril.

In consideration of all this, the water, as represented by analysis No. III, will in future be used as well for the boilers of the Lackawanna Iron and Coal Company, as also for city supply, by the Scranton Gas and Water Company. The place from which this water is taken lies outside the coal measures, and, as already stated, about half a mile above the mouth of Dunmoore Creek, where for the first time, Roaring Brook receives mine water.

The proportionally large amount of sulphuric acid in IV to VII is derived partly from Dunmoore Creek, into which a number of collieries are emptying their mine water; further from mines along Roaring Brook, or near to it, and below mouth of Dunmoore Creek, as well as from heaps of culm, (waste-coal), slags, cinder, ashes, &c., piled up below that point, on both banks of Roaring Brook, all of which contain more or less sulphur, in such combinations as are soluble by water.

Concerning the unusually large proportion of organic matter in Nos. V and VI, it is necessary to mention that, for local reasons, both places are not kept as clean as the use to which the water is taken would demand; otherwise said substances would probably not exceed 8, instead of 16 and 19, as they amounted to then.

In the majority of waters, such as are used to feed steam-boilers, the carbonate salts are prevalent, and these are less troublesome than any of the other salts; free acids in water are in general only met with in extensively worked mineral regions and volcanic territory. Excluding the so-called mineral waters, containing often 1,000 and more pounds of foreign chemically combined matter in every 12,500 gallons of water, and which are seldom used for steam-boilers, the average quantity of foreign matter in other waters, rivers, spring and pump water used in boilers, foots up to about 40 pounds, at most, of sediment, on evaporation of 100,000 pounds of the water.

While this is probably the average, it may be well to call attention to the wide range within which that number is obtained, lying between half a pound to 300 pounds and over. Thus it will be seen that the general expression of, "why! water is water," has only value so far as humanity merely cares for its passing by; while, if compelled to make use of it, and reach a certain aim, which in this case is making steam, it will probably be preferred to look more closely into the matter. It will pay to use water that deposits but $\frac{1}{12\frac{1}{2}}$th of an inch thick layer, in preference to another leaving a total residue (in the same time) of $4\frac{1}{2}$ inches in thickness, could either be had within a reasonable distance from a given locality. True, these are extreme cases, yet they serve to give a better idea of the problem.

However, accustomed to move and to meet every day's demands, the following calculation on an average quality of water will be given by me, in order to show how rapidly the sediment accumulates, even under such circumstances as are often practiced, viz: Admitting a boiler of 40 horse power; length of boiler 35 feet, diameter 4 feet 6 inches, with 2 flues, each 18 inches diameter, working to its full capa-

city, and uninterrupted day and night for a whole week, blowing off only at the end of the week. Sediment left on evaporation of 12,500 gallons, 40 pounds; specific gravity of the sediment, 2.4. Incrustation gathering equally thick on lower one-third of the circumference of the boiler, which presumption is near enough for this purpose; actually it is found to be thickest at lowest point, (and near the grate,) and thence decreasing to an edge, on either side toward the point where the flame or gases of combustion no longer reach the boilers, that is where the actual heating surface is at an end, and also some around the flues.

Under the conditions, as enumerated above, there is:

Total quantity of water required for whole week, 357,120 pounds.
Residue in boiler, derived from said water, 143 "
Thickness of incrustation at the end of the week, $\frac{1}{15}$ inch,
or if allowed to run on for a whole month, which
is often done, then the accumulation will be $\frac{5}{16}$ inch,

which of course could be lessened by blowing off a little now and then during specified time. Now there are a good many works where the boilers are not cleaned until they utterly refuse producing steam of required pressure, notwithstanding that the double and triple amount of coal is consumed on the grate.

From such places I possess specimens of boiler incrustations three-fourths to one inch thick; naturally, with such a bad conducting lining inside the boiler, the latter must be kept red-hot, if steam at all shall be kept up by it. To say the least, it is certainly unwise to proceed thus; the little steam that is made is bought at a very heavy expense in coal, the iron is being blistered, and if (what occasionally does occur) anywhere a piece of the sediment separates from the rest, an explosion is almost the inevitable result, because under such circumstances the water suddenly comes into contact with the red-hot iron; steam is produced so rapidly, that in most cases it cannot escape quickly enough from the boiler, the steam pressure increases above the boiler's capacity of resistance, and off it goes.

The remedy for above named evils is:

To select of two or more waters at practicable command that which contains least foreign matter and no free muriatic acid, nor free sulphuric acid.

Should all waters, or the only water at disposition, carry the acids alluded to in a free state, then saturate the latter, either directly in the boiler or in a separate tank or reservoir, with, for instance, "pow-

dered raw bi-carbonate of soda," after which the boiler will remain intact.

Where the water is very impure, both chemically and mechanically, the last mentioned operation is best fulfilled in a reservoir, the more readily if the mechanical impurities are of such a character as to settle within 12 hours, when comparatively clear water will reach the boiler.

If the best water at hand cannot be obtained in sufficient quantity, take as much of it as is available, and use it in mixture with the other source of water, provided, of course, the additional cost of piping be not in excess of the advantages derived thereby.

In this way free muriatic acid or sulphuric acid in the one water can be saturated often by the other water, thus saving expense for treatment with artificial powders, which, for example, is the case when water of analysis No. III is mixed in sufficient quantity with that of No. V or VI; namely, the free sulphuric acid of V and VI being the stronger acid, will expel the carbonic acid of the carbonate of lime, &c., in No. III and form sulphate of lime, &c. If, for particular financial reasons, erection of tanks, reservoirs or artificial powder treatment cannot be resorted to or afforded, and yet the water is very impure, then blow off and clean out at shorter intervals, though it may be more expensive in a long run. Last, but not least, employ none but reliable and experienced men to attend the boilers, and allow them sufficient time to thoroughly clean the boiler whenever needed.

Whether, in a given locality, it be best to blow off frequently, which causes a larger consumption of fuel; to replace a boiler by a new one in perhaps every eight years; to treat the water with suitable materials in the boiler; or to erect reservoirs, in which to settle mechanical impurities, get rid of part of the organic matter, saturate free acids and even precipitate some of the chemically combined matter, by which means a boiler may be made to last 20 years or more—all this naturally depends on the quality of the water at disposal.

While in some instances the water needs no attention at all, in others again but ordinary care, there are some that occasion considerable loss in greater consumption of fuel, irregularity in the operation of works depending on such boilers, and by the shorter time they are serviceable.

To be sure on all these topics, and to get the most power out of a boiler at least expense, it seems proper, after the question of a sufficient supply is favorably settled, to have a chemical analysis of said water; should this examination show the necessity of treating

the water before entering the boiler, then prepare next one or more general plans of mechanical appliances needed, simply drawn in pencil and to scale, so as to be enabled to make a close estimate of cost of their execution. Of the different plans made, select that which offers most advantages, compare its cost, maintenance, (and materials for chemical treatment, if needed), with the savings in coal, in regularity of operation and longer endurance of the boiler, and if the account falls in favor of the additional appliances, then use the same; while if it shows the contrary, then of course dispense with them.

But even when the latter case should be found preferable, the preliminary work cannot be considered a loss, as by its means information is gained regarding the proper caution required to be observed in the use of the water, or rather, in the management of the boilers using such very impure water.

Finally it must be added that, in general, river water is better adapted to boiler purposes than either spring or well water, because its chemically combined foreign substances are mostly less than those in the latter waters; while the larger amount of mechanical impurities in river water can be separated more easily and cheaply from it than the chemical impurities of other waters.

Hyde Park, Pa., Feb. 23d, 1872.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from page 34.)

The relation of small shafting to hollow shafting.—"On small shafting, pulleys are used very much less in diameter, consequently the friction of the shafting is as its velocity. If the circumference of the pulley is used for the bearing, the friction is very much increased. The torsion of the hollow shafting is as the cube of its diameter; if you use a 3-inch shaft the torsion of that is as its cube. If you take from the centre of the shaft, you have left the outside shell only, so that the amount of power gained theoretically, is the amount of iron taken from the inside of the shaft, running upon the bearing of the outer.

"One difficulty in small shafting is in properly fastening the pulleys. The construction of this shafting is such, that it requires a larger diameter to hold the pulleys than to transmit the power; consequently, I have taken $1\frac{3}{16}$ inch diameter as the smallest shafting

that it is practicable to run in mills. An inch shaft, well sustained, will drive 100 looms; but you have to fasten to it the couplings, the pulleys, and set-screws; and if the holes are not properly drilled, the set-screws will cramp the shaft. After putting up a line 150 feet long, it is necessary to straighten it. You cannot straighten the line of shafting in the shop, because the pulleys are not made in the shop. In order to straighten the shafting, we take a lever, put it under the rail, and spring it into place.

"We are using a line of $2\frac{3}{16}$ inch shafting, driving 16,000 ring spindles. The quantity of oil required to lubricate this shafting is so small, that, if I tell you, it will seem almost impossible. I asked the overseer how much oil he used in oiling this shafting,—and he told me only two or three drops to a bearing, once a week; and said that he would run the whole line a year with a half pint of oil.

"I found one shaft had been running eighteen months with no dripping pans underneath; the overseer giving as a reason, that the quantity of oil consumed was so small that none were required. We all know that it requires oil to run a shaft, and we can form an idea of the amount of friction by the quantity of oil consumed.

"The line of $2\frac{3}{16}$ inch shafting, which drives 16,000 spindles, runs through a mill 350 feet long, and is fitted up with bearings 8 feet apart, and carries a reasonable share of pulleys which drive the machinery.

"I have adopted this method of having the main driving pulleys about once in 150 feet; and counter lines about 150 feet long, and belted in the middle. The middle shaft is made $2\frac{3}{16}$ inch diameter.

"If the pulleys are very small, it requires, to run at a slow speed, more power than it does through gears, on account of the strain which you are obliged to put upon the belt. In England it is the custom to use gears mostly to transmit the power, which requires a stiff shaft to hold them in place; consequently, a gear never yields; it must go. With a belt it is very different. In making the formula for shafting, I adopted as a standard one-fifth of the breaking weight. There is no pulley put on strong enough to run more than this; but with gears it must go.

"*Gearing.*—There are many ways of transmitting power from the motor to the machine, or place where it is to be utilized. I will invite your attention to the three that are commonly in use among our manufacturers, viz., Gearing, Shafting and Belting. Gearing and shafting transmit a uniform motion, that is, a certain number of revo-

lutions, but not always a uniform revolution, owing to the elasticity of the shaft or imperfect construction of the gearing. Power transmitted through pulleys by belts or straps is variable, and cannot be relied upon when uniform motion is required, owing to the elasticity and thickness of the belts, and their liability to slip. Power transmitted through gears and pulleys may have an increased or diminished velocity by having gears and pulleys of different diameters. But with shafting the velocity is positive, as by construction both ends of the shaft must run with the same number of revolutions. Each of these methods has its advantages, but neither motion in all cases can be made to supply the place of the others. When a positive ratio is required, between the driver and driven, it must be through gears; and as gears are universally used to transmit power from the water-wheel or water-wheel shaft to the second mover, let us for a few minutes consider gears and their formation. Possibly no part of mechanical science in common use is so poorly understood or wretchedly abused as the formation of gearing. Each draftsman or mechanic has his favorite tooth or form of tooth. It is his pet child and there is no other like it. To ask him to demonstrate or explain why it is better, would be considered almost an insult; but however perfect it may be in theory and construction, if the gears are not properly adjusted to each other, and made to run as designed, the whole theory and mechanism becomes useless, as the teeth are formed for a definite pitch and cannot be used for any other, either theoretically or practically, when a smooth motion is required.

"In forming teeth for gears we first draw what is called the *pitch line*, or circumference of uniform motion, which is the working diameter of the gears. The teeth are formed from this line, and it is indispensable to the smooth running of the gears that these lines should run together, otherwise there would be a grumbling noise or jar, like the rolling of a fluted roll over a plain hard surface. I think I can demonstrate to any geometrician, that a tooth similar to the epicycloidal and hypocycloidal tooth is the only one that can be made to run smoothly.

"This tooth is formed by having two circumferences run together corresponding to the pitch line or diameter of the required gears. However, as this is not the proper place to discuss theories, I will not occupy your time by doing so. Within the last month I have started a new Turbine water-wheel of about 350 H. P. The crown gear 7 ft. dia., and jack gear 4 ft. dia. The teeth in these gears are paral-

lel below the pitch line, and when started they did not run smoothly. I had them ground together with tallow and emery, and they at once commenced forming a tooth similar to the epicycloidal tooth.

"In discussing the properties of gears, I have come to the following conclusion. First, That the loss by transmitting power through gears is $1\frac{1}{2}$ per cent. in the driver, $1\frac{1}{2}$ per cent. in the driven, and $1\frac{1}{2}$ per cent. in the teeth, in all $4\frac{1}{2}$ per cent.; *i. e.*, when the diameter at the pitch line is eight (8) times that of the *bearing*. If the diameter is only four to one, then the loss is double, or 9 per cent.; *i. e.*, the friction or loss of power is inversely, as the ratio of the diameter of gears to their bearings. In this statement I have not considered the weight of the gears or shaft. In horizontal shafting the *weight* has no effect, as the weight of the gear seldom is equal to the pressure upon the teeth.

"Secondly. If intermediate gears are used in transmitting power, and the three axes are in the same plane, the friction is double, or 9 per cent. in lieu of $4\frac{1}{2}$ per cent. If the driver and driven have different diameters, the opposite sides of the teeth in the intermediate must be of a different shape, *i. e.* made to conform to the different diameters of the driver and driven. Thirdly, for the same reason, the driver cannot admit of two driven gears of different diameters at the same time and run smoothly.

"As the destroying force or concussion is as the square of the velocity, and velocity of contact is to the pitch of teeth, as verse sine to sine. I have therefore adopted, to transmit the greatest amount of power with regard to durability, the following formula for first drivers, and made tables to correspond. Let d = dia. in feet, p = pitch in feet, and H. P. = horse power: then $\frac{d}{(6\sqrt{d}+1)} = p$, and to find the velocity of the periphery in feet, multiply the square root of the diameter by 750 feet, or $750\sqrt{d} = v$, and $d^2\sqrt{d}\left(\frac{1}{6\sqrt{d}+1}\right)^3 \times 2200 =$ H. P., *i. e.*, if the pitch and velocity are obtained by the above rule, and the breadth is two and a half times the pitch, which I think will be found correct for spurs, and two and one quarter for bevel gears.

"Usually I think the pitch of gears is too large for the diameter to insure good results. An increased pitch on the same diameter will not transmit more power, as the velocity will have to be diminished

to make it run smoothly. These formulas are intended for the smaller gear, the larger is not to be considered.

"There are advocates for the rolling of gears together, *i. e.*, the teeth can be so formed that one tooth can be made to roll into the other; but I think this can be shown to be theoretically and practically impossible.

Table showing the Diameter, No. of Teeth, Pitch, Velocity, Revolutions and Horse Power of Gears.

Let. *D.* = dia. in ft. *T.* = No. teeth. *P.* = pitch in inches. *V.* = velocity of periphery in ft., and *H. P.* = horse power.

Dia. in Feet.	No. of Teeth.	Pitch in inches.	Velocity of Periphery in ft. per min.	Revolutions per min	Horse Power.
1	22	1·72+	750	238·8	44
1½	26	2·15+	915	194·7	86
2	30	2·53+	1057	168·3	137
2½	33	2·86+	1187	151·1	197
3	36	3·16+	1299	137·8	263
3½	38	3·43+	1403	127·5	337
4	41	3·69+	1500	119·3	414
4½	43	3·93+	1591	112·5	499
5	45	4·16+	1677	106·7	590
5½	47	4·38+	1759	101·7	682
6	49	4·59+	1837	97·4	783
6½	51	4·74+	1912	92 6	993
7	53	4·98+	1984	90·2	1004
7½	55	5·16+	2053	87·1	1115
8	56	5·34+	2121	84·4	1233
8½	58	5·52+	2186	81·8	1357
9	59	5·68+	2250	79·5	1483
9½	61	5·85+	2311	77·4	1607
10	60	6·01+	2371	75·4	1738
10½	64	6·16+	2430	73·6	1876
11	66	6·31+	2488	71·9	2020
11½	67	6·46+	2543	70·3	2167
12	68	6·61+	2598	68·9	2311
12½	70	6·75+	2651	67·5	2462
13	71	6·89+	2704	66·2	2610
13½	72	7·02+	2755	64 9	277:3
14	74	7·16+	2806	63·8	2932
14½	75	7·30+	2856	62·7	3099
15	76	7·44+	2904	61·6	3262
15½	77	7·55+	2953	60·6	3429
16	79	7·68+	3000	59·6	3604

"If gears are firmly sustained and well adjusted, and the teeth actually cut in the epicycloidal form, 33 per cent. can be added to the velocity indicated in the above table. This will increase the horse power in the same ratio.

"*Shafting.*—We will next consider shafting and the transmission of

power through the same, the theory of which, I presume, is well understood by you all; it is, therefore, only in the adaptation that I may differ with some or all of you.

"Wrought-iron shafting of 1 in. diameter will transmit from 14 to 15 H. P. at 100 revs. per. min. before there is any set twist. You will observe by this that a shaft is seldom twisted off, but is usually broken by jar of gears, or being out of line, or by transverse pressure. A shaft 2 in. dia., 100 revs. will transmit 100 H. P. before twisting, but will frequently be broken with very much less power if out of line; while 1 in. to 2 in. shafting, being flexible, will hardly be influenced by small variations. You will perceive from this that torsion is hardly to be considered in shafting a mill, as it will require larger shafting to prevent springing by transverse pressure than it does for torsion. With prime movers, or wheel shafts, we can afford to pay an extra insurance in loss of power and weight of iron, as there is usually but one or two in the mill, and should any accident occur to these it would cause the stopping of the mill, and the loss might cost the price of a dozen shafts, I have, therefore, taken one-fifteenth ($\frac{1}{15}$) of the twisting weight, or the cube of the diameter, &c., $\frac{d^3 \times R}{100} =$ H. P. For second movers we have the formula $\frac{d^3 \times 2 \times R}{100} =$ H. P. For third movers or mill shafting, $\frac{d^3 \times 3 \times R}{100} =$ H. P.

"In advocating small shafting, I do not pretend that, theoretically, there is any saving of friction in transmitting the same amount of power. It requires the same amount of friction for a 1 in. shaft as it does for a 6 in. shaft, if both are equally strained; as a 6 in. shaft, of course, would run very much slower to transmit the same amount of power, but that in most cases the diameter is larger than is required, as the transverse pressure requires a larger diameter than the torsional, as before stated.

"This led me to consider if there might not be some way devised to meet this difficulty. In most of our mills the bays are about 8 ft., and require shafting of about 2 in. dia. to sustain the lateral pressure of a card or loom belt; yet this same shaft has torsional strength at 150 revs. to run 900 looms before twisting, although it may not be running more than 8 to 10 looms or cards when near the end of the line, while a shaft $\frac{3}{4}$ in. dia. is all that is required to perform that amount of work, if well sustained. To meet the difficulty I have made

a cast-iron rail, so constructed that the hangers slide along the whole length of the line without regard to the beams. By this arrangement there can be as many hangers as are required, one to each pulley, if necessary. The number of bearings do not increase the friction if properly arranged, as it is by this rail. I use this rail for all shafting less than $1\frac{7}{8}$ in. dia., where the bays are 8 ft. I have running two lines 160 ft. each. Each line driving 60 breaker cards and lap bead; its dia. is $1\frac{3}{16}$ in. to $1\frac{5}{16}$ in., and runs 280 revs. per min.; driving pulleys on shafting for cards, 7 in. dia. I have also about 1500 ft. more driving cards and looms; about half of it has run 16 months without any repairs. I would here state shafting might be much smaller but for the difficulty of having it made thoroughly in our workshops. The pulleys must be well balanced and nicely bored, or the set screws or keys will spring the shaft.

"I use this rail in connection with shafting for cards and looms. It is not so necessary for spinning and other machinery, as the machinery on them are a greater distance from each other. I have, in one of the Lawrence Manufacturing Co.'s mills, a shaft $2\frac{3}{16}$ in. dia., running 416 revs. per. min., in common Babbit boxes, driving 14,000 ring spindles, $1\frac{5}{8}$ in. ring; this shaft has run 18 months without any repairs or extra labor whatever. It has no self-oilers, but is oiled once a week with a common oil can, using a mixed oil of two parts sperm and one part Downer's paraffine.

"We have another line of shafting 300 ft. long, $2\frac{3}{8}$ in. dia., running 433 revs. per min., driving 15,000 throstle and mule spindles, with full complement of machinery. This shaft has run about ten months; about one-half of it was not under cover, being exposed to the cold weather of last winter. This line has given no trouble. I have yet to see a shaft less than $2\frac{1}{4}$ in. dia. twisted off, and hope if any one present has they will state the fact and circumstances to the meeting. I have often seen larger ones broken by being out of line, and I think this is one of the strongest arguments in favor of small shafting. I think one-half of the friction and three-fourths of the weight of the shaft can be saved over the old system of small and quick shafting well arranged. One can hardly afford to waste a large amount of power to drive the heavy shafting of a large mill, to prevent an outlay once a year or so of some small accident that *may* possibly occur. And furthermore I claim it is better that a small shaft should break, than hold so firmly, as in case of a large shaft it would do, as to cause injury either to life or machinery, as the case may be.

Self protection is the first law of nature, we are told, hence civil engineers always construct mills with a view that nothing shall give out in the future, no matter what its present cost in material and power, as they know full well their reputation is at stake; and should any of their work need renewing in a year or so, they would be condemned. Furthermore, they construct with the knowledge that inferior capacities may run the machinery, and we all know by experience what and how great those difficulties are.

Horse Power of Shafts,—Speed 100 *revs. per min.*

FIRST MOVERS.		SECOND MOVERS.		THIRD MOVERS.			
Dia.	Horse Power.	Dia.	Horse Power.	Dia.	Horse Power.	Dia.	Horse Power.
3 inch.	27·00	2½ in.	31·25	1 inch.	3·00	3 3-16 in.	97·15
3¼	34·33	2¾	41·59	1 1-16	3·59	3 1-4	102·98
3½	42·87	3	54 00	1 1-8	4·27	3 5-16	109·04
3¾	52·73	3¼	66·86	1 3-16	5·02	3 3-8	115·33
4	64.00	3½	85·74	1 1-4	5·85	3 7-16	121·10
4¼	76·76	3¾	105·46	1 5-16	6·78	3 1-2	128·62
4½	91·12	4	228·00	1 3-8	7·79	3 9-16	135·63
4¾	107 17	4¼	163·52	1 7-16	8·91	3 5-8	142·90
5	125·00	4½	182·24	1 1-2	10·12	3 11-16	150·42
5¼	144·70	4¾	214·34	1 9-16	11·19	3 3-4	158·20
5½	166 37	5	250·00	1 5-8	12·87	3 13-16	166·24
5¾	190·10	5¼	288·40	1 11-16	14 41	3 7-8	174·55
6	216·00	5½	332·74	1 3-4	16·07	3 15-16	183·13
6¼	244·14	5¾	380·20	1 13-16	17·86	4	192·00
6½	274·62	6	432·00	1 7-8	19·77	4 1-16	201·12
6¾	307·54	6¼	488·28	1 15-16	21·81	4 1-8	210·56
7	343·00	6½	549·24	2	24·00	4 3-16	220·28
7¼	381·07	6¾	615·08	2 1-16	26·32	4 1-4	230·29
7½	421·87	7	686·00	2 1-8	28·78	4 5-16	240·60
7¾	465·48	7¼	762·14	2 3-16	31·40	4 3-8	251·22
8	512·00	7½	844·74	2 1-4	34·17	4 7-16	262·14
8¼	561·51	7¾	930·96	2 5-16	37·09	4 1-2	273·27
8½	614·12	8	1024·00	2 3-8	40·18		
8¾	669·92	8¼	1123·02	2 7-16	43·44		
9	729·00	8½	1228·24	2 1-2	46·87		
9¼	791·45	8¾	1339·84	2 9-16	50·47		
9½	857·37	9	1458·00	2 5-8	54·26		
9¾	926·86			2 11-16	58·23		
10	1000 00			2 3-4	62·39		
				2 13-16	66·35		
				2 7-8	71·29		
				2 15-16	76·04		
				3	81·00		
				3 1-16	86·16		
				3 1-8	91·38		

—Daniel Hussey, Esq., Lowell, Mass, from Proceedings of N. E. Cotton Manufacturer's Association, No. 10, *April* 19, 1871.

Chemistry, Physics, Technology, etc.

ON THE PRINCIPLES OF GUN CONSTRUCTION.

By Lieut. C. E. Dutton, U. S. Ordnance Corps.

[*Concluded.*]

When the art of manipulating and forging large masses of steel began to develop and give signs of rapid progress, it was hoped by many that the time was near when the gun-maker would be able to avail himself of a metal possessing in the highest degree the qualities he desired to utilize. But the record of steel guns forged from a single ingot, cannot be construed otherwise than as a failure to sustain this expectation. The following list of burst guns, of that construction, is by no means complete, though it comprises all the cases of which I have been able to procure accounts apparently authentic.

This record has been sufficiently varied and extensive to leave no uncertainty as to the proper conclusion to be drawn from it. It is of no moment to say that other guns of similar constructions have endured severe trials: no record can be good enough to wipe out such a list of failures. Herr Krupp has virtually conceded this by abandoning that system, and now builds up all of his large guns by shrinking hoops of steel over a central tube with initial tension. Some of these guns, it will be noticed, were made of puddled steel; and if it be urged that this metal cannot be compared with cast steel, the plea cannot be denied. But they serve to show at least this much—that the tenacity is by no means the only element of strength which the gun needs, for the average tenacity of semi-steel is nearly double that of cast iron, and is rather higher than that of the steel put into guns which have exhibited extreme endurance. Nor can it be urged that the weakness of puddled steel is solely due to the fact that it is a mass of welds; for the breaks in these guns do not follow the welds at all. It is unnecessary to pursue this part of the subject, and we may confine ourselves to the brief statement that puddled steel has incomparably the worst record of any metal ever put into a gun.*

It has been frequently observed by those who employ mechanical

*The hoops furnished by Messrs. Petin et Gaudet for banding the French and Swedish cast iron rifles are made of puddled steel and are highly esteemed. The whole method of treatment in the manufacture of these rings is peculiar, and the resulting metal has a character distinctively its own. It is not intended to include them in the above category.

LIST OF FAILURES OF SOLID FORGED STEEL GUNS.

Kind of Gun.	Calibre.	Weight.	Round at which failure occurred.	Bursting Charge.		
				Powder, lbs.	Shot, lbs.	
America.						
1. Wiard 50 pdr.....	5·″1	5700	9	5	50	Nov. 7, 1861.
2. " "	"	"	10	5	50	Dec. 6, 1861.
3. " "	"	"	1	5	50	Dec. 9, 1861.
Several Wiard 12 pdrs. and guns of other makers have also burst.						
England.						
1. Fletcher 6 pdr., S. B.	3·″62	.....	1	4¼	6	
2. Morgan's 12 pdr.....	3·″12	1550	6	2¼	15	June 27, 1860.
3. Lynall Thomas 7″....	7·″	14500	16	25	175	Extreme proof.
4. Krupp 6 pdr.....	3·″5	1800	2	5	18	Nov. 18, 1861.
5. Mushet's 20 pdr.....	3·″7	2700	132	5	180	Extreme proof.
6. Krupp 7″.....	7·″	.....	2	18	110	Jan. 29, 1867.
France. Three instances only are known, but the details are not full.						
Belgium. Two instances with imperfect details.						
Prussia.						
1—6. Six Krupp 4 pdrs., old pattern, on the Wahrendorff plan, are reported to have burst in action during the Austrian campaign, but details not given.						
7. Krupp 72 pdr.....	8·″	14900	.....	34½	180	Aug. 8, 1865.
8. Prussian 4 pdr., not Krupp's.....	3·″	1100	130	1¼	10	Sept. 27, 1867. Killing an officer and a gunner.
9. Krupp 72 pdr.....	8·″	14800	650	27	180	Jan., 1869.
Italy.						
1. Krupp 72 pdr.....	8·″	14800	43	17½	180	
Sweden.						
1. Bessemer steel gun....	5·″2	7200	61	8	56	Aug., 1864.
2. Semi-steel gun.....	4·″8	6500	1	5	44	
Russia.						
1. Krupp 96 pdr.....	9½″	30000	.....	40½	270	April, 1864.
2. " "	"	"	56	"	"	June, 1866.
3. " "	"	"	.....	"	"	Jan., 1868.
4. " "	"	"	.....	"	"	July, '69. On board a frigate, occasioning great loss of life.
5. A rifled muzzle-loading gun.....	"	.....	66	40½	270	These guns were bored from solid blocks furnished by Krupp.
6. Do. do. do.....	8·″	.. ..	109	31	180	
7. " " "	"	.....	50	25	180	

tests, that very perceptible differences are manifested in the tenacity of specimens which are intended to be identical in all respects except sectional area, and that the larger the area (*ceteris paribus*) the less the tenacity. The difference, which is marked and unquestionable, seems at present to be anomalous. A parallel fact, and one having possibly a relation to it, is that the larger specimens do not elongate so much as the smaller ones of equal original length. In the case of the large steel rods broken by Mr. Eads, the small specimens elongated very considerably, and endured over 100,000 lbs. per square inch, while the very large ones did not elongate at all (that is to say, did not elongate to that extent which may be called ductile yielding) and broke at strains near 30,000 lbs. per square inch. Is it possible that as we increase the sectional area of a tension rod of steel the ductility and tenacity both diminish? or that the elastic and ultimate limits approach each other? This hypothesis is supported by some recent tests made by the late Lt. Col. Rodman of a large block of steel procured from the Bochum Mining and Manufacturing Company of Westphalia.* There seems to be no satisfactory explanation at present available for this anomaly. It is thought by some that carbon is abstracted in the heating furnace. Others seek to explain it by the effects of slower cooling in large masses. The latter explanation is more tenable. We have been in the habit of associating with extreme tenacity and strength a very finely granular and fibrous fracture. The fracture of a large mass of steel is always coarser than that of a small one. We know, also, that these appearances are profoundly modified by the rate of cooling,† and it is very easy to convert a coarse fracture into a fine one by merely re-heating and cooling rapidly; in other words, by "hardening" or "tempering."‡ It is known, too, that the rate of

* Sample bars were cut from the exterior and interior of the block. The tenacity of the exterior was about 58,000 lbs. and of the interior a little over 53,000 lbs. per square inch. The samples tested were 1·″128 diameter—a standard dimension for all test specimens in the Ordnance department. This is much larger than is employed in Europe. Thus at Woolwich the diameter is ″·625, and sometimes less. In Russia it is about ″.7, and in Sweden ″.25. It is noticeable that Swedish tests are generally very high. Steel wire has been known to resist 250,000 lbs. to the square inch, and the strength of wire bolts and cables is well known.

† The slow cooling of the Krupp gun blocks was promoted by throwing them into hot ashes and cinder from the furnaces, after hammering, where they were allowed to remain.

‡ The tenacity of the Firth steel, used in the tubes of the Woolwich guns, varies from 25 to 31 tons per square inch before the oil tempering to which they

cooling alters the relation which the carbon holds to the iron, the manner of which we need not pause to explain.

Yet all the allowance which can properly be made in this way seems insufficient to account fully for the numerous cases of rupture in the solid forged steel guns, and we might postulate as a second and co-operative cause the explanation suggested by Mr. Mallet for the weakness of wrought iron guns forged from a single ingot. In these cases the action of the hammer was evidently confined to the exterior portions, and, instead of condensing the interior of the forging, induced such a state of initial tension that a fissure would open in the axial parts. This is the reverse of those conditions which theory and practice alike indicate as necessary to secure the highest restraining power of the metal. It is safe, therefore, to assert that steel allows of no such simple reasoning as is employed in treating generally of the properties of metals. In passing from the small pieces pulled asunder in the testing machine by a measured stress, to the large blocks used in a gun, there enter some qualifying factors of which the ordinary logic does not take account.

There is one important feature of nearly all the known systems of gun construction which should not be passed over, viz., the principle of "initial tension." This consists of disposing the metal in such a manner that when the gun is at rest the interior portions are in a state of compression, while the exterior ones are in a state of tension. This adds much to the strength of a gun, for it compels the outer portions to sustain more and the inner portions less than they otherwise would sustain in the act of firing. This important feature was first introduced about twenty-five years ago, by the lamented Rodman, and has since become almost universal. It is produced in cast iron by cooling the interior more rapidly than the exterior, by use of a water core. Air is sometimes used, especially in Sweden, and is

are subjected. After the tempering the tenacity varies from 42 to 50 tons. The elastic limit is between 12 and 14 tons before tempering, and between 28 and 32 tons afterwards. Krupp does not temper his tubes, but the Russians do. The tenacity of Krupp's steel may be reckoned about the same as Firth's; The enormous tenacity sometimes assigned to Krupp's steel is apt to mislead the ill informed: it gives the same results as other steels of the same constitution, when tested in the same way. The quantity of carbon best suited to these tubes is ½ per cent. This is Krupp's and the Russian standard, and I believe also Firth's, but Krupp's, steel contains a notable percentage of silicon, amounting in some analyses to ·44 of one per cent., an amount which is generally considered to be decidedly injurious.

necessary with the Swedish iron, which appears to contract more in cooling than our American gun irons. From some unexplained cause, irons smelted from magnetites contract more than those from limonites, and hence the water core becomes necessary, to secure the proper amount of tension, in our guns,* which are made from limonite irons. We gauge the amount of tension by cutting off a ring from the muzzle while in the lathe. This ring is planed through by a radial cut, and springs asunder when the tool is nearly through, showing a tendency to unroll. By measuring the amount of gape, we have a comparative notion of the amount of tension. In built-up guns the successive cylindrical layers are shrunk on hot, while the barrel itself is cool. Generally, when the gun consists of several layers, the amount of tension given to each layer increases from the tube outwards, the outer layer being strained very considerably. Subsequent firing, it is believed, always tends to relieve gradually this tension, by stretching the metal permanently, and this is one cause of the diminished strength of guns after protracted service. But let us proceed now to glance briefly at the prominent systems of gun construction in various foreign countries, and witness the applications of these ideas.

The system of gun construction adopted in England is the so-called Woolwich system. In a general way, it may be called a modified form of the Armstrong system, which consists in surrounding a central steel tube with wrought iron coils. The modifications are highly important. The Armstrong gun, as now built at the Elswick factories, near Newcastle, consists of a steel tube, with a heavy jacket of longitudinal bars welded together, inclosing the rear end. The remainder of the tube and the jacket are surrounded by numerous coils, shrunk on and "hooked" together. The Woolwich gun dispenses with the jacket of longitudinal bars, and reduces the number of coils to a minimum, *i. e.*, two or three large coils, instead of numerous smaller ones. This reduction of number is a great improvement on the score of economy, and appears to involve no sacrifice of strength. But the chief point of difference is the elimination of the jacket of longitudinal bars. This was, of course, designed to give longitudinal strength; but this great axial strength is, in the first place, excessive, and, in the second place, is obtained by the sacrifice

* The Parrott guns, on the contrary, are from magnetite irons, and the great inequality in their endurance was thought by Rodman to be attributable to this cause.

of circumferential strength at the very locality where the wrought iron part of the gun should possess the most of it. As is well known, the strength of an iron bar, in a direction perpendicular to its length, is very much less than the longitudinal strength; the welds, also, are planes of weakness in the jacket. The Woolwich gun, very properly, does away with this, and is apparently a stronger construction. The English constructors have a pious hatred of both steel and cast iron, on account of what they term their "treacherous" character, and maintain that they use steel in the bore, not for its strength, but for its hardness and freedom from welds, which are necessary in coils. They depend upon the coils for the restraint against bursting, and consider the steel tube a mere lining, charging upon the tube all failures. On the other hand, the opponents of the Woolwich construction say that it is weak, because the soft wrought iron, with an inferior elasticity, relaxes its grip on the central tube after a few fires, giving it very little support, and compelling it to sustain, almost unaided, the stress of firing. But experience seems to sustain neither view completely. It can be shown, I think, that the Woolwich people very much underrate the efficiency of the steel tube, and somewhat overrate the efficiency of the coils, while their adversaries as obviously are guilty of the reverse error. If either party could prove its position, it would prove what is not a fact, viz., that the Woolwich gun is a very bad gun. In their eagerness to condemn steel, and to glorify wrought iron, the Woolwich constructors have thrown a boomerang, and their opponents have answered by firing at random. These are the impressions produced upon an unprejudiced observer, who has carefully studied the records, so far as they could be learned.

To undertake to give even a condensed summary of the record of the present Woolwich construction is a serious task. That record has been a long, uncompromising, severe one. No system of construction has ever been tested so severely, and hence it is difficult, if not impossible, to institute a comparison between it and any other record. We may, for purposes of discussion, divide the Woolwich guns into two classes with respect to calibre: 1st, guns of 9 inches and smaller calibres; 2d, guns larger than 9 inches. The record of the first class has been emphatically good. It is not entirely unblemished, but, on the whole, it represents so much triumphant success, and so little disaster, that any attempt to impeach it looks like captious criticism. These guns have, in many instances, endured over 1000 rounds with heavy charges; a still greater number have endured over 500 rounds. A few guns have exhibited inferior endurance, but they represent, in

nearly every case, the earlier stages of the present construction. One instance occurred where a 9-inch gun burst explosively at the first proof round; but it may be fairly argued that a gun belonging to an established system of construction is not a candidate for a record, as a part of the system, until after it has passed the regulation proof. The results of a regulation proof must be held to be applicable, not to the system, but to the particular gun under proof. Respecting guns over 9 inches calibre, the record is not so clear. One 10-inch gun has fired over 400 rounds without injury, but no guns of the latest Woolwich construction, of largest calibres, have been put to extreme proof. The new 35-ton gun appears to have exhibited signs of weakness prematurely, and the present indecisive stage of the record, as far as it goes, points to the conclusion that the Woolwich system displays its highest efficiency in guns not exceeding 9 or possibly 10 inches calibre. No 12-inch English gun has survived 270 rounds.

The system adopted by Russia and Prussia is the new Krupp construction. It consists of a very heavy central tube of steel, surrounded by successive series of steel hoops, shrunk on with powerful initial tension. This construction contrasts strongly with the old, and, on principle, is a great improvement. The hoops are rolled in a tire-mill, and being necessarily very short, can exercise only a circumferential resistance. The longitudinal strength is abundantly supplied by the central tube, which projects far enough to the rear to accommodate the breech closure (or fermeture). The only question which can be raised is respecting the central tube. This is very massive—almost a gun by itself—and is forged from a large ingot, which loses half its weight in the lathe. May there not be in this tube a remnant of the weakness found in the old solid forged guns? The restraint of the hoops may be expected, however, to counteract any such weakness, if it should be proved to exist, but not completely. The strength of the metal in the hoops is higher than that of the tube, which may be attributed to the widely different manner of working up the scantling, as well as to its smaller size and different mode of cooling.* There is, therefore, an excess of strength in the hoops, and if a modern Krupp gun should be disabled, we might anticipate that the failure would occur in the tube.

The objection raised against an all-steel gun by the English con-

* Tires are cooled by a jet of water playing on them, after they have been rolled to gauge and before they are removed from the machine. Besides preventing distortion, this actually increases both the strength and hardness of the tire.

structors is, that this metal is treacherous. We have seen, in the cases of solid steel guns, that there is much reason for this belief; but in the built-up guns the record shows no such thing. To explain the failures in the former guns, we are obliged to resort to what are, at best, merely probable hypotheses, and yet, by the light of subsequent experience, so probable that we are justified in assuming their correctness in the absence of any better ones. There is nothing in the past to throw doubt on the assumption that, if we can insure the presence of proper tensions, the absence of adverse tensions, and avoid the interference of vibratory waves, steel is as safe a metal as wrought iron. All of these adverse conditions are aggravated as we increase the masses exposed to them, and the method of building up the gun is a safeguard against disaster from either of these causes. The initial tension from the wrong direction is obviated, and that from the right direction secured by it; and the contact of surfaces of successive layers, having small or moderate thickness, prevents the propagation of dangerous vibrations. The record of the new Krupp guns abundantly sustains these views. The only failure is that of an 11-inch gun, at Cronstadt, which blew into fragments the front part of the tube forming the chase, at the eighth round—the body of the gun and its hoops remaining on the carriage, otherwise uninjured. The circumstances of this mishap were peculiar. It appears that the shell broke up in the gun, and it is believed to have wedged in the chase. The accumulation of pressure thus produced, together with the *vis viva* of the gases suddenly checked, are believed to have caused the rupture. It is of course impossible to prove the correctness or the incorrectness of this explanation. There is nothing intrinsically improbable in it, notwithstanding the fact, that in a vast majority of cases where projectiles are broken in the gun, nothing more than a trifling local injury is produced, or even no injury at all. On the whole, it seems proper to give the gun the benefit of the doubt, and consider this failure as not indicative of any special weakness, but the result of a mishap, which can seldom occur in so disastrous a manner. And yet there is a lingering suspicion that these heavy steel tubes inherit a trace of the weakness shown by their predecessors, the solid forged guns; but we will hope otherwise. Assuming that this instance proves nothing and unsettles nothing, let us look at the remainder of the record of the Krupp guns.

1. The first trial gun has fired 410 rounds without injury; the calibre was 11 inches.

2. Another 11-inch gun has fired about 1080 rounds without injury.*

3. A 9-inch Krupp gun (228.6 millimeters) has fired 712 rounds at Berlin. A small crack appeared in the chamber after the 662d round, which enlarged somewhat during 14 subsequent rounds, but did not increase during the last 36 rounds.

4. A similar gun has fired 825 rounds without any material injury.

5. Another 9-inch gun has fired 400 rounds without injury.

6. An 8-inch Aboukoff† gun has fired 1300 rounds without material injury.

7. A 9-inch Krupp gun has fired in Austria 650 rounds, and is still serviceable.

8—9. Two 8 inch guns, constructed on Krupp's plan, by the Bochum Company,‡ have each fired upwards of 500 rounds, and are serviceable.

A considerable number of 6-inch siege guns (Krupp's) have fired more than 1000 rounds each during the late war, and no failures are reported.

In justice to other systems, it should be stated that these large Krupp guns have been fired almost always with the prismatic powder, which is exceedingly mild in its action,§ while the Woolwich 9-inch guns have fired a powder of very violent character. It might also be stated that even cast iron guns have shown extraordinary endurance. Some of those used at Paris seemed to do about as well as Krupp's, and it is reported that an 11-inch Swedish rifle has fired 1100 rounds. But notwithstanding this, the record of the Krupp system of hooped guns is, so far, a triumphant one, and though it may be impossible to institute an exact comparison with other systems, it is safe to pronounce it eminently successful.

It may be of interest to compare the Krupp construction with that of Mr. J. Vavasseur, of the London Ordnance Works. The Vavasseur gun consists of a steel tube, with hoops of the same metal. The tube, however, is much thinner than Krupp's, and is jacketed from the

* It is barely possible that these two 11-inch guns are one and the same, though I think otherwise. This record has been a difficult one to procure, though for the most part it is founded on the best authority.

† The Russian government constructs guns essentially on the Krupp plan at the Aboukoff works, near St. Petersburg.

‡ This information was given me verbally by a reliable informant.

§ The highest recorded pressures in the 11-inch trial gun were about 66,000 pounds, and the average about 46,000 pounds per square inch, which is a very low average for a gun of that size. The diameters of the cartridges are considerably smaller than those of the chambers, which greatly relieves the pressure.

breech to a short space beyond the trunnions, with a second tube shrunk upon it—the hoops encircling the jacket. The unjacketed part of the tube is also hooped clear to the muzzle. In this gun the strength is cast more upon the hoops, and less on the tube, than in Krupp's, and the initial tension is more effectually carried out. Mr. Vavasseur's gun is certainly worthy of more attention than has been bestowed upon it.

The construction adopted by the French, Belgian, Dutch, Danish and Swedish governments for large rifles, is cast-iron hooped with steel. This manner of building a gun is not to be commended. It involves a fallacy. A gun all cast-iron would be rather stronger than one of equal dimensions with steel hoops, because the cast-iron in the exterior, for a given amount of stretch, would exercise a greater amount of restraint than the steel. The ultimate tenacity of the metal has nothing whatever to do with this case, because in any event the degree of strain upon the outer portions is far below the useful limit of strength of good cast-iron, and much more so of steel. It is solely a question of extensibility. The less extensible the metal is, under a given stress, in the outer parts, the greater is the force required to give it a certain amount of stretch. As this elastic force measures the amount of restraint exercised, it follows that the less elastic metal will exercise more restraint in the exterior. Let us illustrate this. Take a French gun turned down ready to receive its hoops. In the act of firing, the metal is stretched, we will say, to such an extent that the circumference of the breach is increased a tenth of an inch. Now let us add another layer of metal—if you choose, with initial tension. When the gun is fired this ring must also stretch a tenth of an inch. In order to stretch our cast-iron the tenth of an inch in ten feet, we must have a tensile strain of 13,000 pounds per square inch. But to stretch a steel hoop a tenth of an inch, we need a stress of only 8800 pounds per square inch; in other words the cast-iron would exercise more restraint than steel in the ratio of 13 to 8.8. There is one condition in which steel would have the advantage. If the initial tension were so great that the cast-iron in the exterior were near its safe limit, then it might be ruptured on the outside, owing to the inferior strength of cast-iron. But practically this never happens in a properly cast gun, and in this country we always take special pains to keep the initial tension of our guns within safe limits.*

* Notwithstanding every precaution, we have lost a number of guns by over-tension, although but one known case has occurred in which such a gun has been accepted.

The use of two kinds of metal in construction is illustrated very well in the methods of Maj. Palliser and Mr. Parsons, for converting cast-iron smooth-bores into rifles by lining them. Maj. Palliser's method consists in introducing a wrought iron tube, made by welding a coil endwise. It is inserted at the muzzle, and held in place by a washer screwed into the muzzle a few inches, and abutting against a shoulder, or rebate, in the front end of the tube. As this mode of conversion is intended only for a special purpose, it should be criticised only with reference to its suitableness to that purpose. It is designed merely as a mode for converting into rifles the 68 pounders and smaller smooth-bores, which are scattered thickly over the world. wide dependencies of Great Britain, in situations whose military importance renders the use of the larger and more costly Woolwich guns unnecessary, or at present unadvisable. They are not regarded as being adequate to inflict damage upon the more heavily armored vessels of the day, and are chiefly located where such a vessel could never go. The vast number of such guns called for a cheap and speedy mode of conversion, and Maj. Palliser's plan seemed to meet the requirements. Three or four thousand guns have been converted in this way, and their performance is regarded by the English as satisfactory.

Mr. Parson's plan consists in introducing a steel tube with a jacket of steel through the breech of the gun, which is cut away for the purpose, and after the tube is inserted the breech is stopped up by a large cascable screwed in. This is a much stronger way of lining a gun than Maj. Palliser's, but it is also much more costly, and the great expense of converting on this plan, coupled with the constitutional distrust of steel and cast-iron inherent in the British ordnance mind, led to its rejection. But the Parson's gun is a most excellent one. The objection to it is that it is too costly to answer for a converted gun, and the fact that it is a converted gun prejudices it* in competition with original constructions.

You would not consider this lecture complete without a statement of the position of the American Ordnance Department, and the character of its material. In speaking on this point, I must disclaim the idea of offering you anything more than the views of an individual, committing no body unless it be himself; and in consideration of the difficulty of the subject, the extreme liability to error, and the wide diversity of opinion the world all over, on the various questions con-

* This prejudice is probably unjust, but none the less real.

nected with the ordnance problem, he hopes he is not committing himself irrevocably.

The United States Ordnance Department is generally regarded as advocating for heavy armament an exclusive system of cast-iron smooth bores. This is not true; it is indeed the reverse of truth. That department has long advocated the use of heavy rifles, and has not the slightest intention to make them of cast iron, unless in our present defenceless condition a war should be suddenly sprung upon us, in which case the question would resolve itself into a choice between cast-iron rifles or none at all. To set this matter on a proper basis, let us look at the plan of armament decided upon for the future, and see what those views are. In January, 1867, a board of officers of high rank, consisting of two from the engineers, two from the ordnance, and two from the artillery, was convened at Washington, at the instigation of the Ordnance Department, to determine the calibres, the number of each calibre, and the proportion of rifled guns for the armament of fortifications. It was unanimously recommended by this board "that the calibres of the heavy ordnance hereafter to be provided for the armament of permanent fortifications should be: For smooth bore guns, 20-inch, 15-inch and 13-inch; for mortars, 15-inch and 13-inch; for rifles, 12-inch and 10-inch; and that guns of other than the above calibres, now on hand, be used in the positions for which they may be most suitable, or in their present positions, until they can be replaced by guns of the calibres above specified." The guns for the defence of New York harbor were also specified, giving the numbers for every fort, and of these a majority were 10-inch and 12-inch rifles.

In January, 1868, an Ordnance Board convened at Washington, and from their report I extract the following: "The Board recognizes the following as the standard calibres of ordnance for land service:

Small arms.

Breech-loading musket calibre, ...	″·50
Revolving pistol, ...	″·44
Breech-loading carbine, ...	″·50

Field guns.

3-inch and 3·5-inch rifle (wrought-iron).
4·62-inch (12 pds.), smooth bore (bronze).
4·62-inch (12 pds.) mountain howitzers (bronze).
1-inch and ·5-inch Gatling guns (on trial).

*Siege guns.**

4·5-inch rifle,	cast-iron.
8-inch howitzer,	"
8-inch mortar,	"
10-inch mortar,	"
5·82-inch (24 pdr.) Coehorn mortar,	bronze.

Sea coast guns.

10-inch rifle,	cast-iron.
12-inch rifle,	"
13-inch smooth bore,	"
15-inch "	"
20-inch "	"
13-inch mortar,	"
15-inch "	"

"The Board recommends, however, that the following calibres be retained in service until replaced by the above:

Springfield musket calibre "58.

3"., 4"·2, 6".4, 8" and 10" Parrott rifles.

5"·82 and 6"·4 bronze howitzers.

6"·4 and 7" cast-iron banded rifles.

8" and 10" smooth bore."

It is true that the large guns recommended by this board were specified as cast-iron guns; but the views of the officers composing it were expressed as follows:

"The success of the experiments with the 12-inch cast-iron rifle at Fort Monroe evidently demonstrates that further trials with cast-iron should be made, and as it is possible that other systems of construction and other kinds of material may give better results, the Board would earnestly recommend the following additional guns to be fabricated and fully tried, viz., one 12-inch cast-iron rifle, lined with steel, and one 10 inch cast-iron rifle, lined with steel. While recognizing the superior strength of steel and wrought-iron over cast-iron, yet, owing to the difficulties experienced in working either of these metals in large masses, in the present state of the arts, and of the still greater difficulty of bringing the metal in large guns, made wholly of either of these materials, into the best condition for resisting the enormous strains to which they are subjected, the Board is of the opinion that it would not be judicious to make trials of these metals in the heavy guns, which

* To the list of siege guns will probably be added, at some future time, a 7 inch rifled gun.

the present construction of vessels of war renders absolutely necessary, until after the results of the experiments herein recommended shall be known, and the state of the arts shall warrant the belief that better guns of large calibres can be made safely of steel and wrought-iron."

If we take into consideration the state of the ordnance problem at the time this opinion was enunciated (Jan., 1868), it will appear to be thoroughly justified. It may have been a singular coincidence, but it so happens that, of the records before that board, the record of cast iron was by far the best. Of all the Rodman smooth-bore guns which had been put to proof, not one had failed, though two ten-inch guns had fired upwards of 4000 rounds, and one fifteen-inch gun upwards of 350, with its proof still in progress. A twelve-inch cast iron Rodman rifle had endured upwards of 400 rounds, and was entirely uninjured. A ten-inch cast iron rifle had endured more than 1000 rounds, failing at the 1047th fire, and the proof of another eight-inch rifle was in progress. On the other hand, the record of the European systems was far from satisfactory. The Krupp solid-forged guns had failed, and the hooped guns had not been tried. The Armstrong guns of large calibre had merely a tolerable record, and I believe that up to this day no English twelve-inch gun has survived 266 rounds. Surely the Board could not have decided otherwise than they did. But a few months changed the aspect of affairs. It was in 1868 that an eleven-inch Krupp gun of the new construction passed a satisfactory proof, and two nine-inch Woolwich guns endured more than 1000 rounds each. On the other hand, our twelve-inch cast iron rifle burst at the 472d round, and an eight-inch rifle at the 80th. Last September, a second twelve-inch rifle burst, at Ft. Monroe, at the 27th fire, and I presume it will generally be considered that those failures settle the question whether cast iron can be safely used for large rifles. The last report of the Chief of Ordnance states that the results attained with this metal are not such as justify confidence in its use for large rifles, and recommends an appropriation to construct and prove a twelve-inch rifle on Dr. Woodbridge's plan, the details of which the inventor objects to making public just at present. The project holds out some promise of feasibility and is in its principal feature a novelty. But as to its ultimate success all surmises are useless. The experiment was recommended by the lamented Rodman, and is regarded by our Ordnance officers with much interest. A small gun has been successfully made on this plan, and has endured an extraordinary proof. But, although much is hoped for, nothing is definitely anticipated.

It appears, then, that our system of heavy ordnance is at present a paper system, and not a reality. It contemplates both smooth bores and rifles of very great calibre. That the smooth bores will be made of cast iron there is little doubt; but the rifles I anticipate will be made of steel. The guns which occupy our parapets are the relics of the recent war, excepting a few fifteen-inch guns. Only two twenty-inch guns have been made, and only two thirteen-inch, and of the latter, one expired after a very creditable endurance. Three twelve-inch rifles have been constructed, two of which have burst, one of them very prematurely.

Since the year 1867 no guns have been constructed for our armament, and only a few for experiment. The reason has been the refusal of Congress to appropriate for this purpose. The all-absorbing spirit of economy has controlled legislation in this regard, and as ordnance experiments are looked upon as a kind of exaggerated boys' play, they have been treated as superfluous luxuries. Another obstacle has been the unscrupulous assaults upon the Ordnance Department by unprincipled adventurers, who have employed the darkest resources known to the lobby to overthrow the Department, because it refused to adopt their inventions without reserve. But we hope that the repeated representations which have been urged upon the proper committees concerning the want of a new armament will have their effect at last, and that before long we shall commence in earnest the work before us. It is time that we made a beginning. Ten years ago our guns were the most powerful in the world, but since then we have remained stationary, and the nations of Europe have gone past us, and are nearly out of our sight.

ON A NEW MODIFICATION OF THE HOLTZ MACHINE.

By C. Van Brunt.

(Communicated by Prof. Henry Morton, Steven's Institute of Technology.)

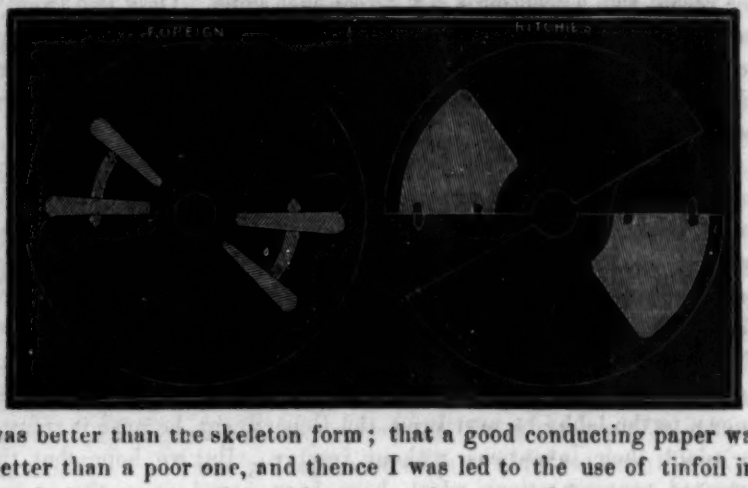
A 16-inch Holtz machine was purchased of Mr. Ritchie and taken to Vassar College; the building was heated by steam. The machine could not be started, and it was brought to my rooms, where, having a large electrical machine in use, I could very readily make it work. Upon receiving the machine, I commenced a series of systematic experiments, and the result I wish to describe.

The latest form of the Holtz machine, as imported, has two "windows" in the back plate, instead of four; a skeleton paper arrangement, with points and a comb crossing in front of the revolving plate,

Mr. Richie imitates by two sectors, and uses continuous paper pieces.

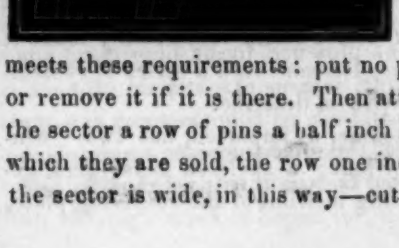
The following are the results of my experiments:

First, I discovered that the action of the machine was much improved by making a *series* of paper points instead of one point; that short points were as good as long ones; that paper in the Ritchie form



was better than the skeleton form; that a good conducting paper was better than a poor one, and thence I was led to the use of tinfoil instead of paper, or rather with paper, using paper, however, only as an insulator. In connection with this, I also ascertained that the form of the hole is of no consequence, a few holes through the glass, a slit, or large holes, as in the foreign machine or Ritchie sectors, answering the same purpose.

The following directions will explain my method of attaching to the Ritchie sectors. I show *one* in the sketch below; they are both alike.



Place a piece of paper on the sector just as Ritchie does in his machine at an angel of about 50 to 60°, and about the width of the collecting points, the outer edge uniform with the edge of the revolving glass, or use his paper if it meets these requirements: put no paper over the edge of the sector, or remove it if it is there. Then attach to the paper along the edge of the sector a row of pins a half inch long, *common pins*, on the paper in which they are sold, the row one inch less in length than the paper on the sector is wide, in this way—cut off a row, leaving a little paper on

each side of the row, turn the paper under the points, backward, and put in a little wedge of card-board; this will make the pins *cant* towards the revolving plate over the edge of the sector; gum it all securely fast. Then paste on the surface of the paper on the sector a piece of tin-foil, of smaller size, leaving a uniform margin of half an inch of paper all around it, except that it should extend to and connect with the heads of the pins. It is now all complete except insulating.

Paste a slip of paper all round the foil and over it half an inch, the strip about an inch wide, and well shellac the surface of the strip and the outside edge. No shellac is needed under the foil or anywhere except outside on the paper strip and its outer edge.

This arrangement makes a perfect conductor to the foil, from the revolving plate, and puts the foil in an insulated pocket, the paper tapering off the tension, as when used around the inside top of a Leyden jar.

The machine, arranged in this way, will jump at once into activity, and produce a torrent of electric discharge. If well shellaced around the edge of the paper it will not reverse or lose its tension, but the sparks will pass certainly to a distance equal to one half the diameter of the revolving plate and perhaps more.

A large Leyden jar, (one to two gallons,) well made, attached to the negative side in place of the small phial, will increase the length, brightness and sound of the spark, and the machine will retain its charge twenty-four hours, and perhaps longer, in ordinary winter atmosphere. This acts as a large and small ball for passage of sparks on an ordinary electrical machine. There is no danger of breaking the large jar, for the small phial acts as a unit jar, the strain is thrown on the phial; this should be protected by a cork the size of the phial, covered with tin-foil pushed down to the inner coating, for the conducting rod to rest upon; the strain is thus distributed. The upper edge of the coatings of the phials should be covered with strips of paper and shellac, to prevent spontaneous discharge.

With this new arrangement of the machine the ordinary phials are sure to break.

The electricity can be reversed at pleasure, by pushing the balls together after it has made or is making long sparks, stopping the machine, then separating the balls half an inch, putting the comb directly across the papers, then turning, and at the same time moving the comb back to its normal position. The sparks will then pass rapidly, and the poles be reversed.

It will sometimes reverse after it is driven at its utmost tension, by pushing in the balls without touching the comb, and if the comb is left too near the foil or paper, it may reverse, after long sparks, of its own accord. The proper place for the comb is an inch or so beyond the paper, over the clear glass. The better the foil is insulated, the less inclination it has to reverse. With foil on the glass without insulation it will not make over a two-inch spark without reversing.

With the arrangement as described the machine runs with little friction—but little of the hissing or frying sound—makes less ozone, and is evidently near perfection.

From some of the experiments, I am led to believe an entire modification of the parts will still further improve it; but this is so great an improvement, with so little cost and trouble, that I deemed it worthy of a description.

CONTRIBUTIONS TO THE SUBJECT OF BINOCULAR VISION.

By Prof. Chas. F. Himes, Ph. D.

(Continued from page 144.)

History of the Stereoscope.

After the full consideration, in the previous pages, of the nature of the pictures which constitute a stereograph, and the manner of producing them, as well as the ocular methods of combining them, it will now be comparatively easy to explain the part that the various instruments, called stereoscopes, play in assisting to overcome the difficulty which, to a greater or less degree, is encountered by every one in attempting to combine the pictures, by any of the ocular methods, so as to obtain the surprising appearance of relief, which our experience leads us to expect only from real objects.

Natural as the preceding methods of combination may appear, and easy as they may prove to most individuals after a short trial, their use seems to have followed rather than to have preceded the invention of the stereoscope. They have been discussed, first, simply because they are best adapted to the statement and elucidation of the fundamental conception involved in the invention of that instrument; the devising of an instrument being indeed a second, and more readily suggested step.

The credit undeniably belongs to Professor Wheatstone for having originated that conception, and of having practically demonstrated its truthfulness. He placed the whole subject of Binocular Vision before the scientific world in a new light by his paper, read before the Royal Society, June 21st, 1838, and subsequently before the British Asso-

ciation, in August of the same year, and by the exhibition, at the same time, of an instrument which he called "a stereoscope, from its property of presenting to the mind the perfect resemblances of solid objects. To understand the principles on which it was constructed, he explained the circumstances which enable us to distinguish an object in relief from its representation on a plane surface." * * * "He next showed that if the object were thus drawn first as it appears to the right eye, and then as it appears to the left eye, and those two pictures be presented one to each retina, in such a manner that they fall on the parts as the projections from the object itself would, the mind perceives a form in relief, which is the perfect counterpart of the object from which the drawings have been taken; the illusion is so perfect that no effort of the imagination can induce the observer to suppose it to be a picture on a plane surface."*

This contribution of Professor Wheatstone's was noticed in the the prominent scientific journals of the day, and the surprise and delight with which it was received in scientific circles sufficiently substantiates its character for novelty. No one was more competent than Sir David Brewster to appreciate it fully, and no one seemed more surprised and gratified, according to the following statement of the proceedings of the Association:† "Sir D. Brewster feared that the members could scarcely judge from the very brief and modest account given by Prof. W. of the principle, and of the instrument devised for illustrating it, of its extreme beauty and generality. He considered it one of the most valuable optical papers which had been presented to the Section. He observed that, when taken in conjunction with the law of visible direction in monocular vision, it explains all those phenomena of vision by which philosophers had been so long perplexed; and that vision in three dimensions received the most complete explanation from Prof. W.'s researches. Sir J. Herschel characterized Prof. W.'s discovery as one of the most curious and beautiful for its simplicity in the entire range of experimental optics."

After the instrument proposed by Prof. Wheatstone had been generally superseded by the lenticular stereoscope, subsequently devised by Sir David Brewster, great efforts were made by the latter and his friends to reduce the claim of Prof. Wheatstone to the simple invention of *a* stereoscope, and that not a very convenient one.

The case can be best stated, and the claims of Prof. Wheatstone, together with the prime fact in the discovery, be set forth by a *resumé*

* Eighth Report of British Association, 1838 (or Vol. vii), notices, &c, p. 16.
† Silliman's American Journal of Science, Vol. xxxv, 1839.

of the historical argument of Sir David against them, without noticing, however, such statements as seem, to the regret of the friends of the latter savant, simply to manifest a spirit of unfairness, and at times incivility towards Prof. Wheatstone.

The fact that the eyes must necessarily receive dissimilar impressions from external objects was one that was noticed at a very early period, and frequently commented upon. Thus Euclid, more than two thousand years ago, demonstrated "that the part of a sphere seen by both eyes, and having its diameter equal to, or greater or less than, the distance between the eyes, is equal to, and greater or less than, a hemisphere." The celebrated physician Galen, more than fifteen hundred years ago, discussed the subject more fully, and enunciated the fact more clearly. The propositions of Euclid were repeated, and passages from Galen quoted by Baptista Porta in his work on Optics, published in 1593, at Naples. In illustrating the views of Galen, he employed a figure which Sir David considered "a much more distinct diagram than that given by the Greek physician," and remarks:* "In looking at this diagram we recognize at once not only the principle but the construction of the stereoscope," and states that a "double stereoscopic picture or slide is represented" by the figure, and thereupon that "Galen, therefore, and the Neapolitan philosopher, who has employed a more distinct diagram, certainly knew and adopted the fundamental principle of the stereoscope; and nothing more was required, for producing pictures in full relief, than a simple instrument for uniting the right- and left-hand dissimilar pictures of the column."

It is not necessary to reproduce the figure alluded to in order to dispose of this argument; for, although it might seem reasonable to allow that Porta may possibly have had some vague notion in regard to the fundamental principle underlying the invention of the stereoscope, although he took no steps to give it a practical demonstration, the following statement, previously made by Sir David,† not only shows that the principle of the stereoscope had not suggested itself, but was inconsistent with his explanation of the phenomenon of distinct vision with two eyes: "Believing that we see only with one eye at a time, he denies the accuracy of Euclid's theorems, and while he admits the correctness of the observations of Galen, he endeavors to explain them on other principles." The explanation of Porta, however, although it will not answer for the distinctive effects of binocular vision, as they have been set forth, is not necessarily to be

* The Stereoscope, p. 9.

† Id., page 8.

considered altogether absurd. In some cases doubtless more, if not exclusive attention, is paid to the impression made upon one eye. It is also still met with occasionally in the same connection. Thus it is reproduced by Dr. Lardner in his popular treatise on Natural Philosophy.* In explaining why, having two eyes, we do not see double, he remarks: "If the two eyes convey to the mind precisely the same impression of the same external object, differing in no respect whatever, then they will produce in the mind precisely the same perception of the object; and as it is impossible to imagine two perceptions to exist in the mind of the same external object which are precisely the same in all respects, it would involve a contradiction in terms to suppose that, in such a case, we perceive the object double. If to perceive the object double means anything, it means that the mind has two perceptions of the same object, distinct and different from each other in some respect. Now, if this distinctness or difference exists in the mind, a corresponding distinctness and difference must exist in the impression produced of the external object on the organs. It will presently appear that cases do occur in which the organs are, in fact, differently impressed by the same external object; and it will also appear that in such cases precisely we do *see double.*" After a full discussion of the subject, in which he takes the moon as the representative of a distant object, he concludes: "Consequently it follows, demonstratively, that all objects which are placed at a distance compared with which the distance between the eyes is insignificant, will convey a single perception to the mind, and will consequently not be seen double." He then, however, discusses the case of such objects as do practically come within the range of the binocular parallax, in a new section, as follows: "*Exceptional cases in which objects are seen double.* * * Let us suppose an object placed so near the eyes that its distance shall not bear a considerable proportion to the length of the line which separates the centres of the eyes. In this case, the images produced on the retina of the two eyes may differ in magnitude, and intensity of illumination, and even in form, and, in fine, it is clear that the apparent direction of any point on the object as seen by the two eyes will be sensibly different. In this case, therefore, the two eyes convey to the mind a different impression of the same object; and we may therefore expect that we should see it double, and in fact we do so. But the observation of this particular phenomenon requires

* Hand-Books of Nat. Philosophy, 1st course, Philada., 1851, p. 174.

much attention, inasmuch as the perception of which we are conscious is affected not merely by the impression made upon the organ of sense, but by the degrees of attention which the mind gives to it. Thus, if the two eyes be differently impressed either by the same or by different objects placed before them, the mind may give its attention so exclusively to either impression as to lose all consciousness of the other."

Distinct reference is, however, undoubtedly made by Leonardo da Vinci, 1584, not only to the dissimilarity of the pictures seen by each eye, but to a consequent *relievo* in the impression of an object obtained by two eyes that is inimitable in "a painting, though conducted with the greatest art and finished to the last perfection, both with regard to its contours, its lights, its shadows, and its colors."

Considerable attention is paid by Sir David to the views of a learned Jesuit, Aguilonius, who, in a work on Optics, 1613, "has some difficulty in explaining, and fails to do it, why the two dissimilar pictures of a solid, seen by each eye, do not when united give a confused and imperfect view of it." His whole effort is to explain away the fancied disadvantage of two eyes, without alluding to any advantage the possession of two eyes confers, and finally he introduces "common sense," as reconciling the slight differences of the pictures, and making a single notion.

In his treatise on Optics, Dr. Smith, in discussing this subject and quoting from and commenting upon Leonardo da Vinci, clearly states not only the dissimilarity of the views obtained by the two eyes, but the advantages as follows: "Hence we have one help to distinguish the place of a near object more accurately with both eyes than with one, inasmuch as we see it more detached from other objects beyond it, and more of its own surface, especially if it be roundish."

So, likewise, Mr. Harris, in 1775, with equal clearness sets forth the advantage of the possession of two eyes, as follows: "We have other helps for distinguishing prominences of small parts besides those by which we distinguish distances in general, as their degrees of light and shade, and *the prospect we have around them.*"

The historical argument is closed by Sir David by the question: "What student of perspective is there—master or pupil, male or female—who does not know, as certainly as he knows his alphabet, that the picture of a chair or table, or anything else, drawn from *one point of sight*, or as seen by one eye placed in that point, is *necessarily dissimilar* to another drawing of the same object taken from another point of sight, or as seen by the other eye placed in a point 2½ inches

distant from the first? If such a person is to be found, we might then admit that the dissimilarity of the pictures in each eye was not known to every student of perspective."

It seems, then, that up to the time of Professor Wheatstone there was undoubtedly a distinct apprehension of the dissimilarity of the impressions of any object obtained by the two eyes, and a consequent possibility that drawings might have been produced representing more or less perfectly such impressions, if, indeed, it cannot be admitted that such complementary pictures had actually been produced by Porta and Leonardo da Vinci. The reconciliation of this dissimilarity with distinctness of perception, in the use of two eyes, however, greatly perplexed some, whilst others clearly saw in it a cause of the decided advantage of two eyes in perception of relief. The clearness and exhaustiveness with which the subject was discussed shows, however, that they did not touch the fundamental conception of Professor Wheatstone, as stated in the quotation given from the Report of the British Association for 1838. Taking up the subject at this point, the following question seems to have presented itself to his mind: If two dissimilar plane pictures, produced upon the retinæ of the two eyes *in observing any object*, in some way or other give rise to a resultant mental impression of relief, may not the production of such pictures upon the retinæ *by means of proper plane drawings of the object*, presented simultaneously to the respective eyes, produce the same effect, —the same impression of relief? He then executed such drawings; he devised an instrument to aid in presenting the drawings so that each eye should receive the one proper to it, and the result was a most beautiful verification of the hypothesis involved in the above question.

It was not, then, the production of the complementary drawings, nor the invention of the instrument to present them properly to the eye, that constituted Professor Wheatstone's discovery; but, after the thought had occurred to him to attempt to employ such drawings in that way, the resources of optical science were ample and varied enough to furnish a variety of instruments to aid him; and it seems natural that he should have looked about for instrumental aid in so apparently unnatural a visual effort as it has been shown to be in the discussion of the different ocular methods.

It seems, indeed, that Sir David recognizes the force of the above facts, and consequently introduces Mr. Eliot, a teacher of mathematics in Edinburgh, who had resolved, without, however, publishing or stating his resolution, in 1834, to construct an instrument for uniting

binocular pictures, but delayed doing so until 1839, five years afterward, and, unfortunately for his claims, the year after Prof. Wheatstone had presented his paper and instrument to the world.

ON THE AURORAL DISPLAYS DURING THE MONTH OF FEBRUARY, 1872.

(Extracts from the Monthly Journals of the different Stations established by the Signal Service, U. S. Army.)

Lake City.

Feb. 12*th.*—A slight aurora.

Feb. 18*th.*—A very bright aurora in the west. This light may have been caused by fire.

Feb. 28*th.*—Spots of aurora throughout the western sky. Weather cloudy.

Feb. 29*th.*—A faint aurora throughout the whole heavens; that in the south somewhat brighter than elsewhere.

Jacksonville, Fla.

Feb. 4*th.*—Aurora polaris visible from 7.25 P.M. until nearly 9 P.M. One nearly perfect arch, streamers quite numerous and of a rose tint, at 8 P.M.

Mobile, Ala.

Feb. 4*th.*—On the night of the 4th a brilliant aurora was visible from 7 to 11 P.M. It became visible in the east, and spread along the sky from a point south of east to northwest, and at times rising in the sky to an altitude of about 60°. At 10.45 P.M. it rose higher, presenting at that time a most brilliant appearance. A portion extending from east to a point east of north, maintained an uniform color varying but little from a beautiful rose to a deep blood. The portion lying between north and northwest and east and southeast were throughout less brilliant, and varying very often in color, sometimes presenting a whitish appearance and at other times deepening to a light rose color; at 9.30 P.M. it disappeared for a short time in the north and northwest, but presenting the appearance of an elliptical cloud in the east, its length being about three times its height, and of a beautiful deep blood color. The base was clearly defined, being about 10″ above the horizon. Between its base and horizon a dense haze existed. It disappeared very quickly at 11.05 P.M.

Cape May, N. J.

Feb. 4*th.*—Clear and pleasant, with brisk and fresh winds. Barometer rising. Red aurora in the evening, in the southeast.

NASHVILLE, TENN.

Feb. 4th.—Weather cloudy. Wind S E. An aurora made its appearance about 6¼ o'clock, extending from east to west; it assumed no definite shape, but was of an extreme bright red color, and was brightest about 8.36 P.M., when it gradually disappeared, ceasing to be seen at 9.30 P.M.

BALTIMORE, MD.

Feb. 3d.—A brilliant aurora polaris was seen this evening, on the southern horizon, between 8 and 9 o'clock.

BOSTON, MASS.

Feb. 4th.—6.30 P.M. Fine display of aurora polaris south of zenith, of a deep red color.

KNOXVILLE, TENN.

Feb. 4th.—8½ P.M. Brilliant aurora; beams shoot almost north to south, and through the zenith. The sky is deep red.

11 P.M. Aurora disappearing very slowly.

MARQUETTE, MICH.

Feb. 5th.—9 P.M. Brilliant auroral display. The arch throughout very well defined, being of a brilliant color, and of not much elevation above the horizon, the streamers moving rapidly along the arch from west to east, and presenting the appearance somewhat of broad waves of light.

10 P.M. The streamers having subsided, the arch is better defined, but not of such a bright color.

11.20 P.M. Aurora more brilliant than ever, streamers shooting up very high. The arch has not been very well defined during the display, rather resembling a great light in the north, with intervals of almost clear sky. Up to 10 P.M. there was no haze or cloud to be seen beneath the arch, but at this writing a few very long, thin, and perfectly straight-edged clouds are seen at the western end of the arch.

Feb. 15th.—11.20 P.M. An aurora is now visible, consisting of an arch, quite well defined, resting upon a bank of thick dark haze at the eastern end of arch; streamers are observed to be shooting both upward and downward, but not to a great elevation upward, while downward they reach almost to the horizon.

11.30 P.M. The arch has merged into a broad sheet of light, and shows signs of disappearing.

Feb. 26th.—8 P.M. Brilliant aurora; elevation of top of arch about 45°, base nearly touching the horizon; colors principally white and pale crimson.

8.30 P.M. Aurora much fainter; but few streamers visible as yet.
11.20 P.M. Aurora no longer visible.

OSWEGO, N. Y.

Feb. 9th.—Northern lights commenced at 11.30 P.M., lasted until 1.30 A.M.; not brilliant.

Feb. 19th.—Northern lights same as described in article 351, page 176, Loomis. Commenced 7 P.M. and lasted until 12 P.M.; nothing unusual in their appearance.

ROCHESTER, N. Y.

Feb. 28th.—The Assistant Observer, Private Tighe, reports, at 9 P.M. last evening, the existence of two luminous arches, extending across the northern sky, being about two degrees apart, and the upper one, the more luminous of the two, about 60° above northern horizon. He is unable to give duration of this phenomenon.

LYNCHBURG, VA.

Feb. 4th.—The aurora borealis was visible during the night of the 4th. At 7 P.M., owing to the cloudy state of the atmosphere, a reddish hue of the clouds was the only indication of the presence of the aurora. As the night advanced the weather became clear, and that quarter of the heavens from northwest to southwest, from zenith to the horizon, presented a bright red appearance. The aurora grew dim in the southwest and brighter in the west and northwest at 10.30 P.M. At midnight the lights became very bright due north, resembling daylight, while in the rest of the heavens the aurora entirely disappeared.

NEW YORK CITY.

Feb. 4th.—Clear weather and brisk northwest winds. At 6.30 P.M. a brilliant aurora appeared in the north, which soon overspread the whole northern heavens. At seven o'clock it had extended eastward and upward until it occupied a space in the southeast from about 15 degrees to 50 degrees above the horizon, about 70 in breadth, and assumed a blood-red tinge, so dense at times as to obscure the stars. On either side of the crimson was a perpendicular line about 10 degrees in width and 50 in length, of a bright orange and green tint. The display lasted until about 11 P.M., when it gradually disappeared.

PHILADELPHIA.

Feb. 4th.—On the north the aurora borealis was displaying, while on the south the aurora australis reflected back with tenfold beauty the light of its cold antipodes. As, at 7.20 P.M., I opened the latticed door of the shelter, a most brilliant display of glorious crimson light struck upon my gaze. Further observation discovered that a

blood tinted light, ever varying, was extending from the south to the southeast. At times the light would subside to a mellow crimson, and again, with gentle flushings, would shoot up towards the zenith. At first I thought the lurid light was the reflection of some conflagration upon the sky; yet, upon opening the east door, I discovered that the northern horizon was also lighted by a pale silvery light, which at times would assume a tinge of pale green. These phenomena remained visible for the greater part of the night, for at 11.43 P.M., when my last observation was made, the rays of the aurora borealis were plainly and magnificently visible above the bank of stratus clouds that interposed above the horizon. The aurora australis had faded; "t'was 'neath a cloud as dark as woe," for huge and black banks of stratus had piled themselves on the horizon, so lately illuminated by the soft crimson light of the australis. The sky was becoming rapidly overcast, and at 1 A.M. was entirely obscured.

ST. PAUL, MINN.

Feb. 4th.—A display of aurora was visible in the north and northwest. It was first seen at 6 P.M.; did not present any particular form, but was a diffused light. It had the appearance of crimson sand falling to the earth, then rolling in billows and waving toward the south, and disappearing. It became more brilliant at 8 P.M., and was then of a deep rich crimson color.

WASHINGTON, D. C.

Feb. 4th.—The auroral display first attracted the attention of the Observer at 7.15 P.M. Presenting a brilliant carmine color, it gradually crept up from the northeastern limit of the horizon till it reached the zenith, when the rays began to appear divided, and presented an appearance as of a flickering flame darting down toward the southwest.

Apart from this track across the heavens there appeared curious globe-like spots of about 15° in diameter, having the same carmine color, and being arranged by the side of the path of the aurora; not less than three of these spots were noticed.

The auroral track was about 40° in width, less brilliant at the borders than in the centre, and when complete could not be seen below an angle of 30°. The observation was continued until 9.15 P.M., the phenomenon presenting but slight changes.

Another, but not confined to any particular part of the heavens, was observed for a few moments at 2 A.M.

Feb. 5th.—The color was the same as the first, but was somewhat less brilliant.